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OLAF HALVORSON, *President*

Saga in Steel and Concrete

NORWEGIAN ENGINEERS IN AMERICA

BY

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PREFACE

THE officers of the Norwegian-American Historical Association, no less than the editors of the Norwegian-language newspapers in the United States, have long known that the engineers and architects born in Norway and educated in the schools of Europe were playing a significant and at times a spectacular role in the development of America. In their discussions of editorial policy, they have always assumed that a comprehensive publication program called for a volume devoted exclusively to the activities of the Norwegian-born technicians who migrated to these shores. In 1939 they were convinced that the time had arrived to begin such a project, and I was asked then to prepare the present book.

A preliminary survey of the sources indicated that this was a field previously unworked by the historian, and that the association had undertaken a task that was something more than a rounding out of its admirable program of publications. It became obvious that a study of the Norwegian engineers and architects would be primarily a first case study in a larger area of research — that of the immigrant as a vital leader in American technology. The information unearthed in the months that followed lent fresh and concrete meaning to an oft-quoted phrase, "transit of civilization," and gave rise to the wish that one day a broader synthesis, embracing the work of all the immigrant technical groups, might be made. It is my hope that *Saga in Steel and Concrete* will be received in the spirit of this wish and be regarded as a contribution to an enlarged interpretation of our European heritage.

Any such study necessarily encounters difficulties, some of them well-nigh insuperable, and unwittingly works injustice to individuals. The difficulties were less numerous and the injustice, I trust, less blatant because of the assistance given me

by the men and organizations discussed in this book. The archives of the Norwegian-American Technical Society, the product of years of active research, are kept at the headquarters of its Chicago branch; these were put at my disposal, as were the materials contained in the *Norwegian-American Technical Journal*. The society has also been most helpful in other ways—in formally endorsing the project, in providing lists of members, in suggesting points of approach, and in establishing the many contacts that were invaluable for obtaining information and appraising technical undertakings.

It is impossible here publicly to acknowledge and to thank all of the engineers of Norwegian origin who in one way or another have made my work easier, more pleasant, and more effective. I should be guilty of gross ingratitude, however, if I did not mention the assistance of several. Waldemar Nielsen, president of the Chicago Norwegian Technical Society, has been kindest counselor of all and a sure guide in my relations with the organized engineers. Axel Wærenskjold of Oakland, California, introduced me to many of the engineers in the San Francisco area. Magnus Bjørndal of Weehawken, New Jersey, rendered a similar service in the New York area. In addition, he generously supplied considerable information, published and unpublished, and he read about half of the chapters in early manuscript form; many of his suggestions were followed in revising these chapters. Like Bjørndal, C. F. Berg of Cary, Illinois, has long been active in collecting records of the Norwegian engineers; he made many items available. His sage advice was most effective in reworking the first four and the last two chapters of the book.

M. S. Grytbak, bridge engineer of St. Paul, gave invaluable assistance in the preparation of the chapter on bridges. The late Magnus Gundersen of Chicago read the chapter on skyscrapers and was generally an unfailing source of technical knowledge and encouragement. Ole Singstad of New York and William J. Wilgus of Claremont, New Hampshire, gave freely of their time and energy in explaining the principles of tunnel-

ing and suggested the inclusion in the tunnel chapter of features and personalities that would otherwise have been omitted. E. A. Cappelen Smith and Anton Grønningsæter, both of New York, read and gave detailed assistance in the preparation and revision of the chapter titled "Men in Metallurgy." In Philadelphia Thorsten Y. Olsen and J. Christian Barth aided in interpreting the careers of their fathers, Tinius Olsen and Carl G. Barth, with whom they had worked as engineers. Ralph Evinrude of Milwaukee did the same for his father, Ole Evinrude. Mrs. Walter Fuchs of Douglas, Minnesota, gave help of a similar nature for the story of her father, Carl Illstrup; as did Bjarne Loss of Lake City, Minnesota, for the sketch of his uncle, Henrik V. von Zernikow Loss. Carl G. O. Hansen of Minneapolis graciously permitted the use of his extensive collection of Norwegian newspaper clippings. My indebtedness to others is revealed in footnotes. To the persons mentioned here or in the footnotes, and to the many others who were generous in their assistance and hospitality, my deepest thanks.

I wish, finally, to express my gratitude to the Norwegian-American Historical Association, which granted me a research fellowship for the year 1940–41 and assumed all expense of publication; to Jean Abell, a student at St. Olaf College, and to my wife, Ellen Herum Bjork, who spent endless hours in typing and collating; to Jane McCarthy of the University of Minnesota Press, who designed the title page and jacket and planned the pages; and to Helen Thane Katz of St. Paul, who made the final editorial changes, compiled the index, saw the book through the press, and generally served beyond the line of professional duty.

Kenneth Bjork

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A MIGRATION OF SKILLS

THE story of the Norwegian engineers in America is a short but vital chapter in the larger story of immigration. The Atlantic migration[1] involved millions of Europeans who were recruited in the main from the peasantry and the industrial proletariat of the Old World, emigrants who, having crossed the Atlantic, settled on the fertile lands of the New World or supplied the labor needed in a rapidly expanding industrial life. The engineers who migrated from Norway to America were, by contrast, few in number and their contribution consisted of applying on this continent the technical skills acquired in the schools of Europe. The story of these men therefore involves a migration of skills in response to the needs of American society.

Though it began in the 1860's, the migration of Norwegian engineers was of little importance before 1879 and it can be said to have ended in 1929, thus covering in all a period of only about fifty years. But the period thus covered was a half century of dynamic change, when our resources were developed in a manner without precedent and our technology altered by an amazing succession of discoveries. It was a period that witnessed the mechanization of agriculture, a revolution in the field of transportation, the growth of giant industrial plants, and the application of new sources of power to the wheels of production. It was a period, too, when the conquest of a continent, begun much earlier, was carried to completion, when vast fortunes were amassed by men of vision and determination, and when great cities grew in response to the needs of commerce

[1] From the title *The Atlantic Migration, 1607–1860,* by Marcus Lee Hansen (Cambridge, Massachusetts, 1940).

and industry. It was, viewed from any angle, a period that profoundly altered our national way of living and thinking and left a heritage of unquestioned material benefits.

In the feverish activity that accompanied these events, Yankee inventive genius, quickened by the demands of American life, was supported by the disciplined skills of the trained engineer, foreign as well as native. America, traditionally on the alert for skills, drew to her shores many of Europe's most talented engineers. Not least among these were the young men from Norway, graduates either of the technical schools of the homeland or of others on the continent. Some were destined to make bold new contributions in their chosen field of activity; others, often no less able, worked brilliantly but with little glory at their varied assignments; while still others successfully moved over into the related field of business management. Whatever they may have accomplished as individuals, as a group the Norwegian engineers left an unmistakable imprint on their adopted country, an imprint which it is the purpose of this study to investigate.

II

Our story goes back in time to the eighteenth century, when a brilliant series of innovations so profoundly altered the economic and social life of England that historians were later to apply to them the name "industrial revolution." Though the transition is sometimes presented as an abrupt one, what the industrial revolution did—broadly speaking—was to apply the slowly accumulated knowledge of science to common economic pursuits and thus to bring about the industrial life and peculiar form of civilization that we know. Specifically, it substituted the machine for human labor, applied steam and, later, oil and electricity to move the machine, and stimulated the growth of an already well-advanced factory system of production. It also increased the output of iron and steel and replaced charcoal with coke as the fuel used in smelting. It promoted the development of canals and improved highways, the railway lo-

comotive, and the iron steamship. It also brought about the mass production of cheap staple products, established modern industrial capitalism, and effected countless social changes.

It is wise to think of the industrial revolution as having roots that reach far into the past. It is also wise to think of it as an evolutionary process that has never ceased. From the familiar changes in the textile and metallurgical industries, the perfection of the steam engine, and the revolution in farming, transportation, and communication, the story moves on to include the production of precision tools, improvements in mining, the discovery of the Bessemer and open-hearth methods of steelmaking, and the coming of a host of new industries. Among the new industrial developments several have been outstanding in recent years — electricity, petroleum, the motor industry, and chemistry.

The men who invented the spinning and weaving machines of the eighteenth century and changed the technology of the metal industry — even Watt of steam-engine fame — were not engineers in the modern sense, despite their inventive genius and general technical skill. The later phases of the industrial revolution, however, were made possible by engineers and by technically trained men of lower rank. One recognized spokesman states that the industrial revolution was "essentially an engineering revolution. During the following century [*the nineteenth*] engineering and its allied arts became the basis of western civilization."[2] In the eighteenth century engineering was identified with war operations; only late in that epoch did civil engineering become distinct from the military, and the nineteenth century saw its development into an honored profession. Craftsmen and classroom mathematicians were replaced as technical leaders by engineers; the training of engineers became a recognized part of the educational function; and societies were formed to protect the interests of men engaged in engineering work. In 1818 the Institution of Civil Engineers was formed in England; its charter, issued ten years later, de-

[2] H. S. Person, in *Encyclopaedia of the Social Sciences,* 5:543 (New York, 1931).

fined the new profession as one preoccupied with the "art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states." The engineers were thus concerned with "the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for the purpose of commerce, and in the construction and adaptation of machinery, and in the drainage of cities and towns."

The increased specialization of economic life and the complexities of production in the nineteenth and twentieth centuries led to many branchings from the profession of civil engineering. Thus mining and mechanical engineering soon became separate fields, and before the nineteenth century had passed, sanitary engineering had attained both respectability and independence. Electrical engineering grew out of the invention of the electric generator and similar equipment, and following close behind were chemical, automotive, and aeronautical engineering. The close relationship of engineering and industry led to the development of a highly specialized branch of industrial engineering. Engineering, itself a product, gave direction to the industrial revolution and became an applied science with many divisions.

III

That the new techniques, so successful in England, should spread to the continent of Europe, particularly in the years after the defeat of Napoleon, was, of course, inevitable; but the extent to which they altered traditional ways of living varied in the different states. In Norway the industrial revolution took place about the middle of the nineteenth century, and it can be said that its progress, while limited, was fairly rapid and its influence great.[3] The work of Frederik Stang, the energetic first

[3] The removal of monopolies and special privilege, the abolition of the British and Dutch navigation acts, and the adoption of a free-trade policy in the period immediately before this, as well as the great expositions of 1851 and 1855 in London and Paris, gave a great stimulus to economic development.

minister of the interior in Norway during the period 1846–56, helped usher in a new era for his country.[4]

It is interesting to note that in 1845 Norway had but three little textile mills; in addition to these there were a few brick kilns and rope factories using no machinery. An additional number of iron and copperworks and sawmills operated in the old tradition. An eloquent testimony of the spirit of the time is revealed in the fact that Norway had 82 tobacco factories, 53 breweries, and 1,387 distilleries! Her population was in the neighborhood of 1,300,000, of which only about 160,000 lived in the towns or cities. Of the urban group most of the workers were artisans or servants. Norway was a distinctly nonindustrial country with a population that was overwhelmingly rural.[5]

This condition, however, could not for long remain unaffected by influences from abroad. In 1845 two young men, natives of Christiania (Oslo), set out from Manchester for Norway, each with a group of spinning masters and foremen. By the next year both had established spinning mills in the Christiania district, while a third enterpriser had started a mill near Bergen. Several years later an interesting venture was begun by Halvor Schou, who started a cotton mill near Christiania and shortly thereafter acquired still another. Schou introduced the steam engine in his mills and produced a cotton fabric of a quality equal to products imported from abroad. In the sixties, following other ventures in the manufacturing field, the Aker River at Christiania was thoroughly industrialized for a considerable distance, one plant along its course employing as many as 400 workers. Despite the predominantly limited operations of these plants, they had a marked effect on Norwegian economy, promoting, among other things, commercial banking and an extensive marketing network. The new factory owner, who as a rule lived in the country where his plant was located, came to consider himself the representative of a new era; he was regarded by others

[4] For an able discussion of his work as minister of the interior, see Bjarne Svare, *Frederik Stang, fyrste bolken, 1808–1856,* 199–353 (Oslo, 1939).

[5] Knut Greve, "Arbeiderne og den nye industri," in *Norsk kulturhistorie,* 4:131, 151–153 (Oslo, 1940).

as a technical leader in production and financial circles, whose ways contrasted sharply with those of the rich and respectable city merchant. With this growth in importance of the factory and the factory owner, there came a corresponding growth in the industrial proletariat. The factory system, with all its attendant advantages and evils, had come to Norway to stay.[6]

The industrial revolution came not only in the form of the factory, with its power-driven machinery, but also as a series of radical changes in transportation and communication. It is significant that between 1820 and 1854 the Norwegian government spent no more than a total of 5,000,000 crowns on roads.[7] Between 1854 and 1886 an average of about 1,000,000 crowns was spent annually for the same purpose. The change was due in no small measure to the work of a military engineer, Christian Vilhelm Bergh, who was brought into the new department of the interior in 1849. Later made director of highways, Bergh planned a number of new routes and rebuilt others, eliminating steep grades. These roads, including some daring and excellent bridges, won for Norway a reputation in Europe as the home of good mountain highways—a reputation that was enhanced by the work of Thomas Bennett in introducing regular travel service about the country.[8]

Steamboats appeared in the extensive coastal traffic of the country as early as 1827, but it was not until the seventies that steam seriously challenged the sail and oar. This retarded development was caused by no real opposition to the steamboat; all, in fact, recognized it as vital and perhaps inevitable. The reason for its slow adoption was thus not lack of public interest, but lack of capital. The early significance of the steam engine in coastal travel derived from the role that it played, between 1827 and 1870, in making the Norwegians machine-minded. We are told that it "made an overwhelming impression, not only on

[6] Greve, in *Norsk kulturhistorie,* 151–174; Wilhelm Keilhau, *Det norske folks liv og historie,* 9:130–135 (Oslo, 1931).

[7] The crown *(krone)* was worth from 20 to 25 cents before World War II.

[8] Georg Brochmann, "Tid er penger," in *Norsk kulturhistorie,* 4:12–31; Keilhau, *Det norske folks liv og historie,* 9:89–105.

women and children, but also on grown seafolk who had been around and seen a bit of the world — yes, perhaps especially on the latter, for they understood better than others what a revolution the steam engine signified."[9] After 1870 the steamboat played a role in transportation the importance of which can hardly be overemphasized.

While the steamboat met with no real opposition in Norway, the reception given the locomotive and railroad was at first not enthusiastic. The difficult terrain of the country and its scattered population caused many to think that railroad construction would never yield benefits commensurate with costs. Nevertheless, Norway was a pioneer in railroad building in north Europe. A government commission studied the problem of railroads and recommended in 1848 that a line be built between Christiania and Eidsvold. After some delay, the Norwegian parliament (Storting) accepted the offer of a British firm to build a railroad with a telegraph line along its entire length and to provide all necessary equipment and rolling stock. The work of construction was completed in 1854.[10] Norway, ahead of her neighbor to the east, thus began in the middle fifties to reckon time in minutes. Several other lines connecting major cities were soon built, and in 1865 a tieup was effected with the Swedish railroads and thence with the continent. While it cannot be said that the country was thoroughly knit together by rail, the locomotive quickened the tempo of Norwegian life and served as another reminder that the machine had come to the Far North.[11]

Warmer than the reception given the railroad was the favor gained by the electric telegraph. The Norwegian government quickly dropped its plans for an "optical telegraph" line, and followed the advice of Carsten Tank Nielsen by adopting a

[9] *Norsk kulturhistorie,* 4:46. For an interesting discussion of the steamboat, see p. 37–54.

[10] It is interesting to note that the route was studied and the railroad largely planned by Robert Stephenson, son of the great Scottish pioneer in the locomotive field.

[11] *Norsk kulturhistorie,* 4:54–60; Keilhau, *Det norske folks liv og historie,* 9:106–118.

comprehensive system of electromagnetic lines. The first unit in this plan,[12] between Christiania and Drammen, was opened for service on January 1, 1855, and the system's growth thereafter was rapid and well received. By 1870 even the remotest part of the country was only seconds from the capital, and the Norwegians soon boasted of having the world's longest telegraph lines in ratio to population. The cable, following close on the heels of the telegraph, linked the country with Denmark in 1867 and with Scotland one year later.[13]

Hardly less important, in considering the adoption of new techniques, was the introduction of a uniform postal rate in 1854; in 1878 the postal service became a part of the international system. The metric system of measurements was adopted by law in 1875, about the same time that decimal divisions for the monetary system were introduced in the national mint.[14]

These and other innovations combined with economic activities of old standing, some of which dated back hundreds of years.[15] In the lowlands of southern and eastern Norway and in the area of the Trondhjemfjord, vast stretches of timber led to an early development of forestry and the export of lumber. The repeal of British and Dutch navigation laws in the middle of the nineteenth century proved a great boon to the Norwegian timber industry. Closely related to this were paper, pulp, and cellulose production. The first mill for the manufacture of paper dates from about 1680, but the modern paper-making machine was introduced only in 1838, and manufacturing in the modern sense began in the early sixties—after a beginning had been made in the production of pulp. The output of cellulose produced from wood began in the following decade. Mining, which dates from the early seventeenth century, was the oldest export

[12] The very first telegraph line was, of course, the relatively unimportant one between Christiania and Eidsvold, along the railroad route.

[13] *Norsk kulturhistorie,* 4:61–67; Keilhau, *Det norske folks liv og historie,* 9:118–121.

[14] *Norsk kulturhistorie,* 4:73; Keilhau, *Det norske folks liv og historie,* 9:121–125.

[15] Among the innovations were agricultural schools, loan offices, modern lighthouses, nail factories, a match plant, and some new machine shops.

industry of the country, the silverworks at Kongsberg and the copperworks at Røros being familiar to the student of seventeenth-century Norway. Iron mining also led to the creation of many ironworks in various parts of the land. Other metals, such as nickel and chrome, came into prominence at a later date; Norwegian nickel, for example, led the world output between 1870 and 1877. Closely connected with mining was the foundry industry, which also got its start in the seventeenth century and which, despite lack of native materials, is still a thriving activity. Dependent in the nineteenth century on England and other countries for coal and even for semi-finished goods, this industry produced a wide variety of products, including cast-iron stoves, propellers, other ship parts, and engineering articles. To these industries may also be added fishing, the preparation of fish products, shipping, and shipbuilding — all of which were affected by the technical changes of the new day. Water power as a source of electricity and the present important chemical industries belong to a later period.[16]

Besides introducing much that was new, and stimulating more that was old, in Norway's economic life, the industrial revolution also had a profound effect upon the social structure of the country. It has already been noted that a new factory-owning type of businessman had come into being and that a new industrial proletariat had appeared on the national scene. It should be added that Norway after 1846 witnessed the growth of a strong new urban middle class. While it is true that there was a middle class long before 1846, in some places powerful out of all proportion to its numbers, it was then only a small part of the total population; it had been, in the words of a Norwegian historian, a kind of "putty between the other classes of society." This situation was changed by the industrial revolution, which, by adding new elements to the middle class,

[16] A reliable guide for a study of Norway's industries is found in the volumes of *Det norske folks liv og historie*. A convenient summary of the chief features of Norwegian economic life, with emphasis on the very recent period, is the *Norway Year Book*, edited by Per Vogt (Oslo, 1938).

made it both extensive and vigorous. In Norway it came to consist of the following:

> Poor members of the bureaucracy and other academic groups that, socially considered, could not live on a level suited to their profession, of normal-school graduates and other teachers, of public and private functionaries, of small businessmen, country tradesmen and shopkeepers, of small master craftsmen, skippers, shipmates, and boatbuilders, of well-to-do fishermen and men in many other economic pursuits. Owners and farmers of the moderate-sized farms in the country belong in the same economic classification, but they were so closely tied up with the other farmers *(bønder)* in class feeling and economic interests that it would be wrong to separate them from the farmer class.[17]

It is unnecessary to suggest that this middle-class group came to be more important in the coastal towns than in the country's interior, particularly if the well-to-do farmer element is excluded from consideration.[18] It is from this middle-class group that most of the engineers came.

IV

Wherever the industrial revolution went, it stimulated a desire for increased technical education. The earliest models of the now familiar technical institutes were, however, the trade schools of France, the Ecole d'Arts et Metiers that Napoleon set up in a number of cities and the Ecole Centrale des Arts et Manufactures erected in Paris by private initiative in 1829. Polytechnic schools began to appear on the continent as early as 1806 (Prague), and even in the eighteenth century Berlin had its Bauakademie. In the German states of the nineteenth century the development of technical education was rapid. The Bau and Gewerbe academies gave way to polytechnic institutes that in turn developed into the familiar *Technische Hochschulen* of recent times. Closer to Norway the Chalmer's Institute (Chalmerska institutet) was founded at Gothenburg, Sweden, in 1829; in the same year Denmark's Polytechnic Institute (Polytekniske læreanstalt) was established in Copenhagen.

[17] Keilhau, *Det norske folks liv og historie,* 9:410.

[18] In this study this group is considered a part, and a significant part, of the middle class.

Finland's first technical school was begun at Helsingfors in 1847.[19]

Norway was in some respects ahead of the rest of Europe in technical training. Kongsberg had a mining school or academy as early as 1759.[20] In Bergen, where the handicrafts were prized, a drawing *(tegne)* school was set up in 1772, and in 1818 the Royal Norwegian Arts and Handicrafts School (Den kgl. norske kunst og håndverksskole) began its work in Christiania, the capital. Similar public drawing schools soon sprang up in other towns. But it was the industrial changes of the mid-nineteenth century that led to an agitation for genuine technical training such as was already available in the other states of Europe.[21]

The sharp upswing in Norway's trade and industry after 1846 caused the practical men who served with Stang to think in terms of technical training. Army and navy officers were also interested because of their concern for national defense. Plans were accordingly drawn up for a school under the supervision of the navy and closely associated with the machine shops of the navy yard at Horten. These were adopted by the Storting in 1854 and an appropriation of slightly more than $1,000 a year was voted for maintenance. The school opened in September, 1855, with 20 students.

It is clear from the records that Horten's Technical School (Hortens tekniske skole) was intended to stress theoretical fundamentals. It trained both naval and civilian technicians, but many of the Horten graduates have achieved — with no further training — recognition in mechanical engineering lines. The subjects taught were basic enough — mathematics, mechanics, drawing, machine study, physics, chemistry (after 1870), and English. A week was devoted to surveying. An entrance exami-

[19] The various encyclopedias—English, French, German, Danish, and Swedish—give adequate accounts of the growth of technical education in the different countries of Europe.

[20] It was discontinued in 1814. Instruction in mining was then taken over by the new university at Christiania.

[21] A convenient summary of the growth of technical education in Norway is Director N. de L. Kobberstad's "Historisk oversikt," in *25-års jubileumsberetning 1912–1937, Bergen tekniske skole, Oslo tekniske skole, Trondheim tekniske skole,* 7–18 (Oslo, 1937).

nation tested the applicant's knowledge of arithmetic, reading, and writing! In practice, however, entrance was far from easy for the civilian students; preference was given to a small group of men with extensive shop experience, most of them of mature age. The period of training consisted of three semesters, thus requiring residence of a year and a half. During the last semester, if the student were both willing and able to follow, he studied differential and integral calculus. One of the great advantages at Horten was, of course, free access to the navy's machine shops, where purely theoretical teachings could be tested by careful observation.

Among the graduates of Horten were such distinguished American engineers as Edwin Ruud, Tinius Olsen, Carl Barth, and Henrik V. von Zernikow Loss—all of them alike in their amazing grasp of mathematical and mechanical fundamentals. They were, to use the words of their beloved teacher, Balthazar Schnitler, brilliant demonstrations that it is better for a school to be "so adjusted as to turn out a small number of technicians with enough knowledge to stand on their own feet, than a great number who cannot." He continues:

> Our school has assumed a peculiar position among the country's technical schools; it has a quite heavy program crowded into a short period of time. This has had the result that a student, to keep up, must be more mature than the one who enrolls at our schools giving long courses. . . . The students' average age is between 20 and 22 years. . . . Our school's reputation rests in large part on the fact that it offers the possibility of a theoretical foundation to older people who earlier have worked in shops and factories, some at home and some in America, and for whom the four-year course as a rule is impossible.[22]

The men of Horten were trained along mechanical lines, particularly in problems relating to the sea; and there was still need in the land for comprehensive training in engineering and

[22] Joh. K. Bergwitz, "Hortens tekniske skole," in *Femti-aars jubilæums-festskrift, Hortens tekniske skole, 1855–1905*, 7–15 (Christiania, [1905]). A short account of Horten is Heitman Altern's "Norway's First Technical School's 75th Anniversary: A Short Historical Review," in *Norwegian-American Technical Journal*, vol. 3, no. 2, p. 1, 13 (August, 1930). The quotation given above is a translation from Bergwitz, p. 13. The account of the Horten school is brought up to date by a *75 års biografisk jubileums-festskrift, Hortens tekniske skole, 1855–1930* (Oslo, [1930]).

architecture. In recognition of this fact, a proposal was made before the Storting in 1857 that two schools — a "school of industry" and a polytechnic institute — should be set up in Christiania. Nothing, however, came of this proposal.

The first technical school of higher rank was founded at Trondhjem in 1870, thanks to a legacy left by Thomas Angell to that northern city. Plans worked out by a local committee and approved by the Storting in 1869 called at first for a three-year technical course, with one year of training common to all students and two years of specialized study. Trondhjem's Technical College (Trondhjems tekniske læreanstalt), which resulted, opened its doors in November of the following year. Until the school year 1890–91, the Trondhjem college had three lines of specialized study and after that date, four. These were architecture, civil engineering *(bygningsfag)*, mechanical engineering, and chemistry. In addition to the customary three years, students not uncommonly chose to remain a fourth year for study in a second major field. Thus a student graduating after three years with a degree in mechanical engineering might elect to remain a fourth year to acquire competence also in, say, the chemical line. Soon changing to a four-year program, Trondhjem's Technical College (familiarly called by its graduates T.T.L.) pitched its work on a consistently high level and counted some of the world's leading engineers among its former students. Such names as Singstad, Giaver, Cappelen Smith, and Grønningsæter suggest the quality of its men and the thoroughness of its training. It is interesting to note that Captain Christian Torber Hegge Geelmuyden, who had acquired a considerable reputation as the first head of the Horten school, left in 1870 to serve as first director at Trondhjem.

Just as the city of Trondhjem took the initiative in starting its famous college, so the other leading cities of Norway, not without considerable rivalry, sought to keep pace with the trend toward technical education. When in 1867 Professor H. Christie submitted a plan for a modestly endowed polytechnic institute, together with a three-year technical elementary school, the

Storting, after some delay, rejected the proposal. The idea was revived in altered form in 1871, when the Christiania Savings Bank, at the suggestion of Professor Aschehoug, decided to give 80,000 crowns toward buildings and equipment for a technical school in the capital. Finally approved, the plans resulted in Christiania's Technical College (Kristianias tekniske skole), which began classwork in August, 1873. Also a municipal project, the new school resembled in many respects the one at Trondhjem. It sought "to impart the necessary elementary knowledge to young men who have decided upon a technical career or who wish to prepare themselves for entrance into an educational establishment of a higher technical level." The Christiania college offered at first a three-year course common to all students; in 1876 the period of education was lengthened to four years and provision was made for specialized training in mechanical and civil engineering in the fourth year; after 1890 it also had a department to prepare chemical engineers. This school enjoyed for a long time a reputation second only to that of Trondhjem's Technical College. The names Olaf Hoff, Mohn, and Berle are a measure of the men it attracted and the training it imparted.[23] The Christiania college, like the one at Trondhjem, required of its students the completion of high-school *(middelskole)* studies.

A third municipal school opened its doors in 1875. This was Bergen's Technical College (Bergens tekniske skole), which owed its origin very largely to the initiative of the Bergen Handicrafts Society (Håndverksforening) in 1870. What the society wanted was a practical trade school that would help preserve and foster the handicrafts of the old Hansa city. After considerable discussion in Bergen, the Storting gave its consent to a technical Sunday and evening school as well as a technical elementary school. As at Christiania, this college, whose detailed plans were approved in 1873, was to give the necessary elementary training to youngsters both for vocational activity

[23] A good brief account of the founding of the Trondhjem and Christiania technical schools is included in Kobberstad's summary in *25-års jubileumsberetning.* The Norwegian encyclopedias supplement this material.

and for entrance into an engineering college or similar institution. In general it followed Christie's early plan, having a three-year course of training common to all students. After 1890, in accordance with a new plan, the Bergen school offered special departments in mechanics and chemistry, thus going the way of the Christiania school. The list of its distinguished graduates, while shorter than those of the schools at Trondhjem and Christiania, includes Aus and a number of other prominent American engineers.

It is interesting to examine the courses required at Bergen's Technical College under its plan of 1890. All students had to take algebra and descriptive geometry, physics, inorganic chemistry, simple mechanics and machine study, structural principles, designing, mechanical and chemical "technology," elements of mineralogy, surveying, heating and ventilation, electrotechnics, Norwegian, bookkeeping, and correspondence. The students specializing in mechanics and chemistry naturally took advanced courses in these fields as well as differential and integral calculus. Students entering the school were required to be at least fifteen years old and confirmed in the state church; furthermore they must have received in the high-school examination at least an average grade *(middelkarakter)* in mathematics or have passed an entrance examination of a quality similar to the one required for completion of the preparatory school. In addition to mathematics the school required a comprehensive knowledge of Norwegian and a reading knowledge of German.[24]

Those who worked for the beginnings of technical education in Norway had in mind elementary training. It soon became clear, however, that the students who enrolled in the schools were generally more mature and better grounded in theory than it was anticipated they would be. In fact they sought nothing less than an engineering education. The schools, it has been observed, soon pitched their training on a higher level than the original plans called for. In this manner they came to "serve

[24] *Festskrift ved Bergens tekniske skoles 25-aars jubilæum, juni, 1900,* 23 (Bergen, 1900). Included in this comprehensive survey is a historical review, "Den tekniske skole 1875–1900," by F. Arentz, p. 3–33.

as makeshifts for a technical institute without being quite able to fill this role, and at the same time to serve as superior technical preparatory schools. The schools, in other words, had as a task the gratifying requirement of training for all the technical positions in industry and technical work generally. A large part of the schools' students aimed at an engineering education and some supplemented their training at foreign, especially German, technical schools."[25]

In addition to the schools already mentioned and those of other European countries, one other institution sent a considerable number of its graduates to America, though usually after continuation study in Germany. This was the Mechanical Trade School at Porsgrund (Skiensfjordens mekaniske fagskole), an experiment in technical education that was begun in 1884. The Porsgrund school, since 1901 a state institution, offered a two-year course aiming to provide young men with sound theoretical study as well as practical training in the machine shop. Its graduates have frequently distinguished themselves in mechanical and electrical fields in America, though some have gone over to other branches of engineering.[26]

It reflects no discredit on the schools at Trondhjem, Christiania, and Bergen to say that technical education in Norway was in many respects unsatisfactory until the country had a state institution on an academic level as high as the German technical *Hochschule*, which had the same rank as a university and required the *artium* examination as a prerequisite for entrance. The need for a state institution was recognized as early as 1833, but the creation of the schools discussed above tended to lessen the demand for such an undertaking. In 1880 a plan for a polytechnic institute was brought forward; after being repeatedly presented to the Storting, it was abandoned in 1890. The proposal that was ultimately accepted was submitted to the Storting in 1900 and accepted in the same year.

It was considered wise to locate the new school at Trond-

[25] Kobberstad, in *25-års jubileumsberetning*.

[26] An able discussion of this school is Ant. Kjølseth, *Skiensfjordens mekaniske fagskole, Porsgrunn, 1884–1934* (Porsgrunn, 1934).

hjem, which was not only the cultural center of a great period in Norway's past but, since it was located near the heart of the country's mining district, had aspirations for an industrial future. Economic considerations postponed the actual founding of the technical institute and caused some changes in the plans of 1900, but finally on September 15, 1910, the school was opened to 100 students. Complete courses were offered in architecture, chemistry, civil, electrical, mechanical, and mining engineering, and naval architecture. Students seeking admission had to pass *artium*. The institute, not needing to concern itself with basic courses, could and did concentrate on four years of intensive engineering training. Growing rapidly with the expanding industrial life of Norway after 1910 and adding specialized departments as they were needed, the new school improved the quality of technical training in the country and raised engineering in public esteem to a level comparable to the pure sciences, law, medicine, the humanities, and theology—fields to which the national university devoted itself.[27]

A total of 3,919 students enrolled at Norway's Institute of Technology (Norges tekniske høiskole) between 1910 and 1935. In these twenty-five years 2,096 engineers and 286 architects were graduated.[28] Up to 1925 it was estimated that about 400 of the graduates did engineering work outside Norway, many of them in North America. The graduates of the new school also assumed the leading engineering role in Norway.

Because the Institute of Technology replaced the older schools at Trondhjem, Bergen, and Christiania in the training of engineers, the entire plan and scope of the latter were changed by the Storting in 1911. Thereafter they were schools for the

[27] Edgar B. Schieldrop, "Norges tekniske høiskole, 1910–20," in *Studenterjubilæet, Trondhjem 1920, en 10-aars historik,* 9–18 (Trondhjem, 1920); Sem Saeland, "Trondhjem's Institute," in *American-Scandinavian Review,* 9:123–127 (February, 1921); Alf Kolflaath, "Norway's Institute of Technology," in *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 1, 7, 15 (July, 1929); and *Norges tekniske høiskole, beretning om virksomheten, 1910–20* (Trondhjem, 1920). Student life is described by Louis Feinsilber in "Studenter-liv i Trondheim," in *Nordmanns-forbundet,* 31:290–292 (1938). *Nordmands-forbundet* became *Nordmanns-forbundet* with the issue of January, 1932.

[28] *Nordmanns-forbundet,* 28:333 (October, 1935).

preparation of technicians, as distinguished from engineers. In their reorganized form they offered two years of training and sought to prepare men as master bricklayers and builders, technical assistants in the state and municipal administrations, draftsmen, contractors, building, shop, and factory foremen, directors of the smaller electric works, shipyards, and other industrial projects—in general those technical positions that lie somewhere between engineering on the one hand and skilled labor on the other. The schools *(tekniske mellemskoler)*[29] thus continued to play an important though quite altered role in the twentieth-century life of Norway,[30] but their graduates, unlike those of an earlier day and those of the Institute of Technology, were to take a minor part in the life of the New World.

V

The students who availed themselves of the opportunities embodied in the technical schools came from that body of Norwegian society which might be called a blending of the old middle class and the new—the merchants, well-to-do farmers, traders, shipowners, shopkeepers, professional men, and lesser bureaucrats who belonged to the Norway of the early nineteenth century, and the factory owners, brokers, and clerks created by the industrial revolution. To be sure, there were sons of a few prominent state officials and of aristocratic merchants, and there were some whose parents were middle class only by courtesy, but the students came for the most part from the towns and cities of the coastal area and from farms with a surplus sufficient to support a promising boy in college.

A glance at the records[31] shows that of the seven engineers known to have left for America in the 1860's one was the son of a court chamberlain, another of a country gentleman, and a third of a wholesale merchant; two were sons of judges, one claimed a skilled workman for father, and the seventh a farmer

[29] In 1936 the word *mellemskole* was dropped and the schools are now called Trondheim tekniske skole, etc.

[30] Kobberstad, in *25-års jubileumsberetning.*

[31] Built up by the writer over a period of several years. The figures given here are merely illustrative of the story that they reveal.

who was also owner of a small machine shop. Of the twenty-two known to have left Norway for the New World in 1880 the parentage of fifteen is traceable. The record reads: five farmers, one newspaper publisher, one broker, one engineer, one merchant, one teacher, two tailors, one machinist, one lawyer, and a ship's captain. Ten years later the situation remained relatively unchanged. In 1890 at least twenty-one graduates left for America. Of these, fathers of five were farmers, three were shipowners and one a shipbuilder; two were schoolmen, one a cabinetmaker, one an engineer, one a merchant, one a lawyer, one a pastor, one a state forester, one a sheriff, one a railway official, one a factory owner, and the last is unknown. The records for 1900, 1910, and 1920 reveal a like situation.

Until the establishment of the institute at Trondhjem, the number who enrolled each year in the technical schools of Norway was small, and the students enjoyed little of the glamor that is usually associated with European university life. They may well have been, as Johan Bojer has described them in *The Great Hunger,* "a motley crowd of young men."

Among them were youths like Peer Holm, who dreamed of being chief engineer because the engineers of the new society were "priests of a sort, albeit they did not preach nor pray." They would take their chances with the others, "some to fall by sunstroke in Africa, or be murdered by natives in China." Some would "become mining kings in the mountains of Peru, or heads of great factories in Siberia, thousands of miles from home and friends." Many would go to the New World and be lost—perhaps for a matter of years, perhaps forever. And a few would remain at home, "with a post on the State railways, to sit in an office and watch their salaries mount by increments of £12 every fifth year."

Not only was the technical course of the nineteenth century a shorter and less expensive one than those requiring *artium* and a university training, but it must be added that, prior to the establishment of the institute at Trondhjem, engineering itself could claim less prestige and respect than attached to

theology, law, medicine, or the academic profession. Literature is a fair barometer of the public attitude, and it is interesting to note that before Bjørnson completed his play *The New System* (Det ny system) in 1879 there was hardly a character in all Norwegian literature who was an engineer.[32] Hans Kampe, in *The New System,* is an engineer and the son of an engineer and he symbolizes both the frankness of America and Bjørnson's determination to "live in truth." Kampe alone carries the banner of truth on a stage overcrowded with engineers; he has lived in the New World and realizes with Bjørnson that appearances have no final value. It is not strange that Bjørnson, with his abounding faith in America, should use an engineer returned from the United States as a symbol of progress. What is really surprising is that other Norwegian writers were so slow to recognize in the engineer, as in the doctor, a figure sufficiently identified with modern civilization to play a leading role in fiction. In Ibsen's *Little Eyolf* (1894) Engineer Borgheim is interested in "a great piece of roadmaking—up in the north," but Borgheim is no great character. John Gabriel Borkman,[33] while not an engineer, is intoxicated with the spirit of the new industry. To him metal sings an unmistakable tune and steamships "weave a network of fellowship all around the world." Looking back on his tragic life, he hears the hum of factories that might have been his. "The night shift is on—so they are working night and day. . . . The wheels are whirling and the bands are flashing—round and round and round." The Master Builder, who immediately comes to mind, is rather a reflection of Ibsen's own artistic yearnings than the architect that he seems at first to be. The engineer, with few exceptions, was not

[32] Some interesting exceptions are worth noting: Bastian Monsen, a civil engineer, in Ibsen's *The League of Youth,* 1869; and Mordtmann, the engineer friend of Fru Wenche, in Kielland's "Poison" *(Gift).*

[33] In Ibsen's play by the same name, published in 1896. Perhaps the first piece of Norwegian literature to pose the problem of the new materialistic civilization versus the traditional order of things was Bjørnson's little story "The Railroad and the Cemetery" *(Jernbanen og kirkegaarden),* published in 1866. This account of a railroad that was to pass over a graveyard found Bjørnson sympathizing with conservative pietism but prophetic enough to see the inevitable victory of the forces symbolized by the railroad.

yet considered worthy of playing a great role in the Norwegian drama. In this, as in other respects, literature only reflected the moods of society.

Not until the twentieth century was there a tendency to use the engineer freely for fictional purposes, and even then he did not appear in an entirely favorable light. With Hamsun, for example, the engineer represents that materialistic or "American" tendency which he fears and abhors and does not understand. With Bojer the situation is different. His novels bristle with engineers, inventors, and scientists, who come neatly off his pen.[34] Granted that they serve, as do all his novels, as instruments of a single idea, they are handled with sympathy and understanding. He knows what it is to stand by a machine as its master—"mind and soul and directing will"—and to gather the power to work miracles. With Bojer the modern technician is "a priest in his way," or, better, "a descendant of old Prometheus." Peer Holm, in *The Great Hunger*, soon becomes sick of the miracles of science, but he is a giant in the earth while his strength lasts.

The engineer's position was unusual in one other respect. The building of highways and railroads and the use of the steamboat, for example, not only provided markets for farm produce and linked the towns with the farms up the valley, but they also brought the *bønder* into a new and strange money economy. Factories that came with the industrial revolution also offered employment to those who sought it. Farms that for centuries had existed under a system of near self-sufficiency and barter found themselves suddenly mortgaged and not infrequently in the hands of strangers. The uprooting of the rural population that followed the introduction of the new economy caused a migration—again greatly facilitated by steamboat, highway, and railroad—down the valley to the city—and beyond. The movement of the country population to the city and the migration to America were two phases of the same

[34] For example, Reim in "Our Kingdom" *(Vort rige)*, 1908; Reidar Bang in "Life" *(Liv)*, 1911; Sigurd Braa in the play of that name, 1916; and Leif Sund, the inventor, in "Day and Night" *(Dagen og natten)*, 1935.

broad tendency in nineteenth-century Norway. This breakup of the self-contained economy of the country has been carefully studied by Ingrid Gaustad Semmingsen in its relationship to emigration;[35] the part played by the engineer, nevertheless, is worthy of special mention.

However important his part in the story of Norwegian migration to America, the engineer himself did not respond to the same urges to leave his homeland. Many of the generalizations that can be made for the causes of emigration as a whole do not apply directly to him. Certainly the usual social and religious motives are missing.[36] The engineers were sturdy representatives of the middle classes and, apart from their purely professional desire for employment, they had no reason to leave a homeland that they loved and which in turn was generally kind to their group. The Norwegians responded quickly to the call from abroad for technical help, but they were in no sense unique; engineers also left the British Isles, Germany, Switzerland, and the other Scandinavian countries, and all of these national groups distinguished themselves in the New World. It is only when we consider the percentage of graduates who left for America that the Norwegian figures are at all significant and we suspect motivations somewhat different from those in the general migration story.

VI

According to one recent publication a total of 1,013 students were graduated from Horten's Technical School.[37] Of this number 211, or about 21 per cent, migrated to America.[38] When

[35] See her "Norwegian Emigration to America during the Nineteenth Century," in *Norwegian-American Studies and Records*, 11:66–81 (Northfield, 1940), and "Grunnlaget for utvandringen," in *Nordmanns-forbundet*, 29:207–209 (July, 1936). For a broad analysis of the various factors contributing to emigration and the theories thereof see Theodore C. Blegen's "Emigration Causes and Controversy," in *Norwegian Migration to America, 1825–1860*, 154–176 (Northfield, 1931), and "People in Dispersion," in *Norwegian Migration to America: The American Transition*, 454–479 (Northfield, 1940).

[36] Exceptions were a very few engineers of *bonde* origin who insisted that the nepotism of the bureaucracy forced them to leave Norway, and several converts of the Mormon faith who were victims of religious persecution.

[37] *75 års biografisk jubileums-festskrift, Hortens tekniske skole.*

[38] Some later returned to Norway.

the record of Trondhjem's Technical College is considered, the results are slightly more impressive. A total of 1,290 regular students between 1870 and 1915 is recorded in the school's publication of 1916. Of these no less than 350, or about 27 per cent, were drawn to America. A supplement to this volume lists an additional 867 regular Trondhjem students, 138 of whom left for the United States or Canada.[39] After 1910 the reorganized technical schools at Trondhjem, Bergen, and Christiania sent a much smaller percentage of their graduates to America, partly because of the rapid industrial developments in Norway after that date.[40] Of the other schools either no records have been published or, as in the case of Bergen's Technical College, they are unreliable.[41] From the figures, however inadequate, it is nevertheless clear that something like one fourth of the students of Norway's technical schools, from the time of the founding of the Horten school to the erection of the institute at Trondhjem, made their way to the New World. During the years of heaviest migration the percentage sometimes ran as high as 40, 50, and even 60 per cent.

Just as the records of the schools are unsatisfactory, so too are the figures dealing with the year-by-year migration to America. The official United States records list collectively the Scandinavian, but not the Norwegian architects and engineers who entered the country after 1897. Inadequate though they are, the government statistics present a picture of the general rise and fall in the migration story and link the exodus of the Norwegian engineers with the similar trek of their Swedish and Danish cousins. The following table gives this information:[42]

[39] O. Alstad, *Trondhjemsteknikernes matrikel, biografiske meddelelser om samtlige faste og hospiterende elever av Trondhjems tekniske læreanstalt, 1870–1915* (Trondhjem, 1916); O. Alstad, *Tillegg til Trondhjemsteknikernes matrikel* (Trondhjem, 1932).

[40] Of the graduates 1,340 are listed, of whom only 81 set out for the New World; *25-års jubileumsberetning.*

[41] The figures given would seem to indicate a total of 181 between 1878–1900; 28 of these went to America. The record is obviously incomplete. See *Festskrift ved Bergens tekniske skoles 25-aars jubilæum.*

[42] Compiled from *Annual Reports of the Commissioner-general of Immigration* and statistical information received from the department of justice. The years given represent fiscal years ending June 30.

YEAR	PERSONS	YEAR	PERSONS
1897	49	1919	124
1898	64	1920	261
1899	56	1921	252
1900	53	1922	136
1901	76	1923	417
1902	145	1924	725
1903	392	1925	315
1904	300	1926	401
1905	209	1927	368
1906	332	1928	209
1907	280	1929	190
1908	137	1930	79
1909	144	1931	33
1910	193	1932	12
1911	225	1933	11
1912	176	1934	8
1913	167	1935	10
1914	177	1936	9
1915	203	1937	29
1916	261	1938	26
1917	259	1939	23
1918	100	1940	35

These figures, in addition to including architects and engineers from the entire Scandinavian North, naturally omit those technicians who went to Canada. The figures also begin too late (in 1897), and the years indicated are fiscal years that end June 30. Recognizing these shortcomings in the official records, the present writer has compiled a year-by-year record of the Norwegian engineers and architects who left for either the United States or Canada between the years 1860 and 1930—a period that encompasses virtually the entire immigration of technical skills. This record was taken from various sources—the publications of the technical schools of Norway, newspaper items, obituaries in American engineering journals, questionnaires, letters, and similar material. Every effort has been made to include only those who were bona fide products of regular technical institutes, whether Scandinavian, British, or continental. No attempt has been made to determine whether the residence of the engineers in the New World was temporary or permanent. The results of this study are presented in the following table:

Year	Persons	Year	Persons
1860	1	1902	67
1865	3	1903	49
1868	1	1904	34
1869	2	1905	46
1871	1	1906	43
1873	1	1907	31
1875	1	1908	12
1876	2	1909	30
1877	1	1910	22
1878	5	1911	20
1879	17	1912	11
1880	22	1913	14
1881	22	1914	7
1882	17	1915	4
1883	19	1916	4
1884	5	1917	4
1885	8	1918	3
1886	7	1919	8
1887	27	1920	8
1888	15	1921	11
1889	11	1922	11
1890	21	1923	32
1891	6	1924	33
1892	17	1925	15
1893	18	1926	32
1894	4	1927	25
1895	8	1928	8
1896	4	1929	2
1897	7	1930	2
1898	8	1931	1
1899	5	1932	0
1900	17	1933	1
1901	35		

This last tabulation, because of the nature of the records available, is admittedly incomplete. Nevertheless, it gives a clearer and more accurate picture of the migration of Norwegian skills than does the information in the government reports, for the official statistics, as is indicated in the analysis presented above, leave much to be desired.

Not a few of the Norwegian engineers and architects returned to the mother country during the twentieth century. Again we must fall back on government records for the Scandinavians

as a whole; these tell the statistical story of those who departed from our shores between 1908 and 1940:[43]

Year	Persons	Year	Persons
1908	61	1925	43
1909	23	1926	31
1910	34	1927	48
1911	40	1928	107
1912	72	1929	81
1913	59	1930	63
1914	70	1931	71
1915	53	1932	43
1916	69	1933	18
1917	52	1934	20
1918	33	1935	32
1919	67	1936	32
1920	65	1937	36
1921	54	1938	32
1922	48	1939	40
1923	30	1940	22

For the period 1925–39 records are available for the emigrant aliens of all races who, in departing, listed Norway as the country of intended permanent residence. Fortunately the departing aliens are listed by professions, and it is reasonable to suppose that most of those who went to Norway were Norwegian-born. The record reads:[44]

Year	Persons	Year	Persons
1925	15	1933	7
1926	8	1934	9
1927	22	1935	9
1928	47	1936	8
1929	23	1937	14
1930	16	1938	10
1931	27	1939	9
1932	17		

[43] Compiled from *Annual Reports of the Commissioner-general of Immigration* and from information received from the department of justice.

[44] Compiled from *Annual Reports of the Commissioner-general of Immigration*. Bjarne Bassøe, secretary of the Norwegian Engineers' Society (Den Norske Ingeniørforening), estimates that about a thousand engineers from all parts of the world returned to Norway during the depression. By 1935 they were once more leaving the homeland in large numbers; *Scandia* (Chicago), January 24, 1935.

VII

The figures given above, especially those compiled by the writer, will be seen to have a close relationship to the business cycle. Men looking for technical employment naturally respond to the rhythm of industrial life.[45] Graduates of Norway's technical schools appear as a mere trickle until the late 1870's, when Europe and America were both recovering from the depression that followed the panic of 1873. Another long depression followed the crisis of 1893 in America, and during this period the migration of Norwegian engineers naturally declined. The longest depression of all — that which followed 1929 — also caused a sharp dropping off in numbers. Short depressions followed the more or less acute setbacks of 1884, 1907, and 1914, and our figures are not unresponsive to these minor disturbances. The periods of prosperity attracted many engineers. Thus the years 1879–93, years of great industrial activity and rising prices, are seen to have been a time of fairly heavy migration except for the falling off after 1883. The period from 1900 to 1907, after the depression following 1893, was the time of heaviest migration, and the recovery after 1908 was rapid. The years 1914–18 were good years economically in Norway, and the uncertainties created by war were a factor in keeping young men at home. By 1923 American prosperity had come out of the reaction of 1921–22, and the industrial activity of the twenties naturally promised much to the young engineer.

Though not without profit, an attempt to synchronize the migration of engineers closely with the short-term ups and downs of American and Norwegian economic life would be misleading. In addition to the relatively brief periods of alternating prosperity and depression on both sides of the Atlantic, one finds that in Norway the last quarter of the nineteenth century and, in some respects, the first quarter of the twentieth were generally unfavorable to the engineering profession because of the failure of the industrial revolution to go substantially

[45] See any comprehensive survey of American economic life. Chester W. Wright's excellent volume, *Economic History of the United States* (New York, 1941), has a useful summary of the American business cycles, p. 868–883.

beyond the preliminary stages of industrialization and transportation development. A fully developed factory system, for example, had to await the utilization of water power, since Norway had no coal. The result was that as late as 1925 a keen British observer and student was able to state:

> The latest mechanical inventions, the most recent scientific discoveries, are within her knowledge, ready for immediate application. The remarkable delay in her industrial development is due, not to backwardness or ignorance, but to natural causes. Having no coal, she has had to wait till the advance of electrical science rendered possible the utilization of her practically inexhaustible water resources, not as a direct motive force, but to create electrical power. . . . In spite of remarkable engineering skill, the development of railways in Norway has been and must be slow and local in its effects. The country as a whole is too difficult and the obstacles too formidable for a rapid growth of railway communication. . . . Now, even on roads whose steepness, narrowness, and unsatisfactory surface seem eminently unsuited to such modern modes of progression, motor-cars running to a fixed time-table are everywhere to be found.[46]

The American economic situation after 1878 was, by contrast, one of general expansion and growth until 1929, despite the temporary setbacks that came as a result of crises or panics. The development of the natural resources of a great continent was to call forth the best efforts of a youthful nation. Land, made readily available by the Homestead Act of 1862, appealed no less to our old American stock than to the land-hungry peasants of Europe. Giant forests fell before the axes and saws of an army of lumberjacks who tripled and nearly quadrupled our lumber output between 1869 and 1909. More impressive still was the record of our mines, which in 1882 made the United States the leading copper-producing country. The coal output jumped from 13,000,000 tons in 1860 to 670,000,000 tons in 1918; and that of iron ore from over 3,000,000 long tons in 1870 to 75,000,000 tons in 1917. Other minerals and great wells of petroleum and natural gas opened up in the New World opportunities undreamed of in the Old.

[46] G. Gathorne Hardy, *Norway*, 265 (New York, 1925).

Essential for marketing the products of the land, transportation facilities kept pace with the exploitation of our resources. Railroad building, interrupted by the panic of 1873, was resumed after 1878, and the period of the 1880's was one of rapid growth, especially in the West and Middle West. Though the following decade witnessed a decline in construction, the Great Northern Railway was completed to Seattle in 1893, and after 1898 growth was again rapid. On the eve of the First World War the United States had more railroad mileage than all of Europe. The improvement of technology was hardly less remarkable. Cheap steel made possible the improvement not only of rails but also of bridges, general equipment, cars, and wheels. Long-distance travel was revolutionized.

In and about the cities the electric railway proved successful. After 1884, when it was introduced in Kansas City, the overhead trolley gradually came into universal use. By the turn of the century, too, such cities as Chicago, New York, and Boston had elevated railways, and interurban transportation was using electricity. Boston took the lead in subway construction in 1898, and New York began its now elaborate underground network of tracks in 1900.

In the twentieth century the automobile, airplane, and superhighway revolutionized even further the whole mode of transportation in America. From 1877, when George B. Seldon took out a patent on an automobile of a sort, tinkering mechanics about the country worked on horseless carriages, and by 1920 there were nearly a million cars in use. Not only passengers but enormous quantities of freight as well were to be carried overland by motor in the twenties, thirties, and forties of the present century. The airplane, like the automobile, got its start in Europe, but it was Samuel Langley and the Wright brothers who in 1902 proved the possibilities of motor travel in the air. Glenn Curtiss flew across the Hudson in 1911, and in 1918 the airplane was used for carrying mail. What happened in the automobile and airplane fields in the years that followed is

common knowledge, as is the remarkable story of highway construction.

The Civil War gave a strong impetus to the building of telegraph lines; in 1862 a line was completed across the continent and development thereafter was rapid. As early as 1866 Cyrus W. Field laid the first successful cable across the Atlantic; cables in all directions were soon to follow. In the middle seventies Alexander Graham Bell and Asa Gray applied for patents on the telephone. By 1912 there were nearly 9,000,000 telephones in America. The wireless, invented in 1895, was introduced about 1900 and in 1913 it was in transoceanic service. Since the First World War the radio has largely replaced the code wireless and has found its way into nearly every home. The typewriter, too, figures in the story of communications since 1876, when the first one was placed on the market. Printing, publishing, advertising, and—on the technical side—the linotype and monotype were also vital in this development.

One of the truly remarkable features of nineteenth-century America was the growth in population. The prevalence of large families, progress in medicine, and a heavy immigration of Europeans caused the numbers within our boundaries to quadruple between 1850 and 1910. Together with this increase in population went a movement from the country to the city and a subsequent growth of cities. Whereas in 1860 only 16.1 per cent of the people lived in cities of over 8,000 population, in 1930 about 49 per cent of the people lived in such centers. This increase in population created a large domestic market for American products at the same time that it provided a large labor force to run the machines of a rapidly developing manufacturing activity.

While it is true that America had a well-established factory system even before 1850, its period of most rapid expansion came after 1865, when manufacturing developed into the largest single contributor to the national income. In the decades that followed the Civil War, America—rich in resources, with good transportation and communication facilities, a great do-

mestic market and an ample labor supply—ceased to be a nation relying chiefly on commerce and agriculture and became instead a manufacturing country. By the turn of the century we were an industrial state, and even earlier, in 1894, we held first place among the nations in the value of manufactured goods. One significant trend was toward the large corporation with enormous individual plants practicing the economies of large-scale production. The best technological improvements and the greatest possible use of mechanical power were introduced in many lines of production, and by 1929 there were over a thousand industrial research laboratories in the United States. It is significant that during the first quarter of the present century the output of the individual worker increased 50 per cent, and that while before 1860 there were less than five thousand patents issued annually, in recent times something like fifty thousand are granted.

Agriculture, too, underwent a great change in the period after 1878. A general scarcity of labor, together with an abundance of land, led to the wide-scale use of farm machinery. In the early seventies the invention of the roller process for reducing flour had profound effects on both the milling industry and agriculture, and John F. Appleby's invention of the twine binder in 1878 was hardly less significant. The combined harvester and thresher, the use of steam and gasoline for power, the improved plow, and many another technological change caused agricultural production to treble between 1850 and 1910. The spread of scientific methods led to higher standards of living on the farm, made larger farms practical, and greatly reduced the amount of human labor required to produce a bushel of wheat or a bale of cotton.

The development of American technical education, while fairly rapid, was for a time much slower than the economic growth of the country. During the first two decades of the past century, West Point Military Academy was the only institution giving systematic training in the engineering arts. A technical school was begun in 1822 at Bowdoin College, but this

venture lasted only ten years. The Rensselaer Polytechnic Institute at Troy, New York, gave a course in civil engineering as early as 1829; and the Lawrence Scientific School at Harvard and the Sheffield Scientific School at Yale, both established in 1847, also offered the opportunity of a technical education. Of the state universities the one at Michigan was first, in 1853, to introduce civil engineering as a regular course of instruction. These, however, were widely scattered and varied experiments in technical training, and it is interesting to note that at the end of the Civil War the graduates of engineering schools, not including West Point, numbered less than 300.

This situation was partly remedied by the passage of the Morrill Act of 1862, which gave to the states public lands as a means of promoting instruction in the "sciences relating to agriculture and the mechanic arts." As a result of this congressional measure no less than 64 technical colleges were founded in the years that followed the Civil War; of these, 50 gave instruction in at least one branch of engineering. The Massachusetts Institute of Technology, which was destined for a great role in American life, was started in 1865, and the Worcester Polytechnic Institute, also of Massachusetts, followed three years later. After 1870 the increase of technical institutes was rapid, the number jumping to 85 in 1880 and to 126 in 1917. The number of students taking engineering courses rose from 3,043 in 1889 to 11,874 in 1900 and to 66,637 in 1928. To protect the interests of engineers the American Society of Civil Engineers was organized in 1852, the Institute of Mining Engineers in 1871, and the American Society of Mechanical Engineers in 1880. In 1884 the Institute of Electrical Engineers came into being, followed in 1896 by the American Railway Engineering Association; in 1908 the American Institute of Chemical Engineers was chartered. But while education reflected unmistakably the changed economic life of the country, and the growth of societies reveals the increasing importance of the engineering profession, America could and did still use the services of men trained abroad. The speed with which most

of the immigrant engineers found employment and the important role they played thereafter are proof that the supply of technical leaders fell short of our national demand.

The America of dynamic growth and change that developed between 1879 and 1929 drew young engineers from Europe as a magnet attracts steel. The extractive industries, transportation, communications, and manufacturing vied for the services of able technical leaders; at the same time they paid good salaries and offered opportunities to men of ability. Even agriculture, or certain phases of it, attracted some; and the building attendant on city, transportation, and industrial growth made the United States a mecca for structural engineers. It was the whole pattern of economic life on this side of the Atlantic, far more than the retarding tendencies at home, that explains why the graduates of Norway's technical schools came to America in search of employment.

VIII

The impulse to emigrate was thus unmistakably economic, or, more accurately, professional. But it must also be remembered that the engineer graduates, particularly in the days before the institute at Trondhjem, were young men. With them, as with most students, the desire to see and live in new lands, to find greater opportunities *(større forhold)*, naturally figured as a part of the broader pattern. The successful careers of some of the first engineers — the pioneers of our story — caused many to cross the Atlantic who might otherwise have hesitated to leave. The presence of friends, classmates, even relatives in the New World also frequently served as a special inducement to try one's luck in North America.

Unlike a large portion of those who left the country districts of Norway to take up land in the Middle West, the engineers burned no bridges behind them; in fact a majority had every intention of returning to the homeland after acquiring experience, perhaps a fortune, and possibly, too, a great reputation. They had no farms to sell and no families to care for. A ticket

for the voyage to America, a few dollars to keep them going until they found a job, some articles of clothing—these with exceptions were all that they carried with them. In a short time they would return to visit parents and friends in Europe; a few years more and they would return to take over engineering posts in Norway. This fact—the tendency of many to regard America as a place of temporary residence only—colored their life in the New World and gave it an orientation that was different from that of the main body of Norwegian Americans. Thus in a social as well as a purely economic sense the story of the engineers is a distinct and in many ways a separate chapter in American urban life.

The thoughts that entered the mind of a young Norwegian engineer just out of college are vividly told in the history of a 1905 graduate of Trondhjem's Technical College. A well-known engineer in Chicago made this statement in a letter to the writer:

> I remember while attending the Technical College at Trondhjem that the newspapers reported farm laborers in the U. S. as receiving up to $5.00 a day during harvest season. Well, eighteen crowns per day for ordinary working-men certainly impressed me! I also remember that my classmates had information from the U.S.A. that men with an engineering education may earn from 60 to 70 dollars a month at the start. 220–260 crowns per month looked very good to me! In Norway I could earn 125 crowns per month, and after ten years perhaps 250. By that time I could be earning 500 crowns per month in the land of boundless opportunities!
>
> But the lure of high pay, although by far the chief factor, was not the only one to influence my emigration to the United States. Trondhjem, at the time of my graduation from T.T.L. in 1905, had a population of about 45,000. Two or three of the graduates would probably find employment there or in the vicinity; those with influential family connections would have the best chance for a position and better pay. The young man had to go somewhere. In most cases there were no opportunities in the home district, very often a farm community. . . .
>
> He knew that he would not feel as much at home in a foreign country as in Norway, but that did not deter him from emigrating. The fact was that he did not care to feel at home anywhere for awhile. . . . He was young, unmarried, and wanted to see a little

of the world, especially the "big proposition" country which he had heard so much about.

I know of no other factors than the above-mentioned which caused us to migrate from Norway. . . . I know of no case, nor have I heard of any before the fateful year of 1940, in which the magnetic power of the Statue of Liberty has pulled a Norwegian engineer or architect across the Atlantic.

Most engineers and architects who left Norway as emigrants had no very definite plan. They had piled up a debt in going through school, and would go almost anywhere to make money. Countries undergoing rapid development offered the best opportunities. To make money as fast as possible, and, as a side issue, to see some other part of the world, was their chief object. Permanent settlement in any particular place was not part of their plan. To them there was only one "home," and for most of them, it would be natural to feel that when they had become a little independent financially they would drift back to settle down in Oslo.

The case of another engineer who eventually returned to fill a prominent position in Norway supports these generalizations somewhat:

I belong neither to the old nor the young engineers who went to America. In 1907, at the age of 22, I was one of exactly 40 students who graduated from Trondhjem's Technical College; of these forty young men, fifteen went to America, and of the fifteen, nine, or about 25 per cent, to the United States. A similar situation is certainly true for the years immediately before and after, both at the Trondhjem school and the other Norwegian technical schools. . . .

What was it that caused so large a percentage to migrate? It isn't easy to answer. Any specific difficulty in finding something to do at home on the part of young engineers, so far as I know, did not exist. For my own part, I found work the day after I left school, and similar experiences were shared by my comrades. The pay, it is true, was nothing overwhelming; we earned from 60 to 100 crowns per month; those who got 100 were considered fortunate. But one did not need more than about 60 crowns, or maybe a little more, to live in a modest way. Each year one could look forward to a small raise in salary. We knew that in America beginning pay was about the same in dollars as in crowns at home. In addition we had the urge to see a little of the world and to try our strength in a bigger field. About the same inducements as send so large a part of American youth to the large city. It was also easy to make the trip; the ticket, as I recall, was about 160 crowns, and there was no difficulty in entering the United States. And of course we

had the addresses of the comrades who had left a year or two before.[47]

The young engineer also usually carried with him letters of recommendation, some school drawings, and the addresses of graduates well established in America. When a Norwegian chief engineer could be found, the chances for employment were especially bright, but the generally high regard in the United States for the work of Norwegian engineers came in time to be his surest recommendation. He made his way to the large metropolitan centers—New York City, Philadelphia, Pittsburgh, Chicago, the Twin Cities, and later to the cities of the west coast; but smaller industrial centers such as Butler, Pennsylvania, and Schenectady, New York, often exerted an equally great attraction. In Canada it was chiefly the paper and mineral centers of Quebec and Ontario, but the maritime and, later, the western provinces were carefully considered for the opportunities that they too offered.

Generalization is particularly dangerous with so individualized a group as the engineers. It can be said, however, that most of them, thanks to the vigorous economic life of America, had little trouble finding jobs; several days or a few weeks usually sufficed, and there are interesting cases of some going to work on the day of their arrival in the New World. In most cases they began as draftsmen or designers at salaries that only experienced engineers could command in Norway. All were impressed by the rapid tempo of American life, the seeming hardness of the city, and the dirt and filth that they found everywhere. But they were quick, too, to appreciate the native hospitality of the average American and the friendly attitude that lay beneath the push and shove of the young society. Their schoolboy English usually proved sufficient for purely professional needs, but many were to find that a mastery of the language was a distinct advantage in the higher positions, especially when dealings with

[47] To the writer, March 11, 1940. The engineer lives, or lived, in Trondhjem, and his letter, written in Norwegian, was inspired by a notice in a technical periodical that the present study would be published by the Norwegian-American Historical Association.

the public were frequent. While advancement proved in most cases to be fairly rapid, not a few came to feel that the higher engineering posts were reserved for native Americans.

But the experiences of the engineers, both technical and non-technical, cannot be expressed solely in terms of the general or typical. The variety of these experiences and the richness of the engineer story as a whole can best be told by following the careers of a few who pioneered on America's technical fronts and left a strong imprint on the material civilization that we call American.

PIONEERING THE TECHNICAL FRONTS

THE Norwegian engineers who migrated to America were a pioneering group. These pioneers, together with technical men from other countries, worked at drafting tables, in shops, and out in the sun. They found new materials with which to build, improved upon others, and then learned to test their strength. They designed machines that frequently started new industries. They laid highways that stretch across our continent, and they altered the cars that—to use Whitman's phrase—roll along the "two-threaded tracks of railroads." They spanned the rivers of their adopted country with bridges of steel and concrete, and they pioneered in the development of the skyscraper—America's unique contribution to the building art. For home and industry they invented many things—gadgets that lighten the housewife's tasks and complicated devices to increase the output of farms and industrial plants. They harnessed the latent power of streams and did much to make ours an age of electricity. They dug into the earth, leaving mines and sewers, tunnels and subways behind them. In metallurgy they introduced fundamental and revolutionary changes and linked American production with that of the world. When the changing needs of industry required, they planned new cities and made old ones habitable. They transformed forests into pulp, often using the techniques of the homeland, and provided the materials for our newspapers and the paper towels in our kitchens. Further, they put the accuracy of science into plant management, to eliminate rule-of-thumb procedure. In these and in many other ways they gave their skills and energy to a mighty development that changed the face and life of the New

World. In doing this, they also wrote their names large in the story of America's growth.

As with all migrations, there were explorers, the men who pointed the way and lessened the ordeal of transition for the later immigrants. The trail blazers among the Norwegian engineers were usually strong personalities who came to America in the 1860's, 1870's, and 1880's, sometimes by way of England, to lead a distinct migration within the larger Norwegian migration. On the technical and industrial fronts their contributions were in many cases original, basic, and vital to subsequent developments. These men, frequently rising to prominent positions, also became magnets directing the course of migration to particular centers of industry. The expressions of helpfulness, kindliness, and friendly interest that adorn their obituaries have a meaning beyond the familiar tributes paid the dead, for they were often the first point of contact in America for younger men freshly arrived from the schools of the homeland. Their reputations once firmly established, they also lent a certain prestige to the schools of Horten, Trondhjem, Christiania, Bergen, and Porsgrund. These early engineers, who had found their way to the centers of American life, largely without benefit of friends or of the experience of others, were in a special sense the pioneers of our story. In their lives, as in the lives of other pioneers, most of the themes of the engineer saga are introduced; and since considerable interest attaches to the leaders of a movement, representatives are here selected from a large number, their careers briefly sketched, and their major contributions noted.

II

Very few trained Norwegian engineers arrived in the United States before or even during the 1870's. An exception was Severin Christian Anker Holth, an inventive genius who introduced the caterpillar principle now extensively used on tractors and similar machinery. Holth was born at Christiania in southern Norway; there his father was a merchant, and there the future engineer received his preliminary education and developed an

interest in electricity and water power. It is reported that Holth, at the age of fourteen, invented a motor with sixteen electro-magnets, that it was exhibited in 1872 at the university in Christiania, and that a professor of physics informed the boy that electricity, while it might be a satisfactory plaything, would never have any practical value.

Shortly after this disappointing experience, Holth entered Trondhjem's Technical College, graduating in 1878 with a degree in mechanical engineering. In the same year he left for America. He settled in Chicago and quickly became chief engineer at the Hercules Iron Works. Holth was next employed in a similar capacity by the McCormick Harvester Machinery Company. In the 1880's agriculture in the New World was fast becoming mechanized, and he turned his mind and hand to designing a group of mowing machines, reapers, corn and rice harvesters, and self-binders that in time were used the world over. During this period he invented a steam-driven plow that moved on a continuous track in the manner of the modern tank.

Holth went to Norway in 1889, rich in experience, to found the American Machine Company at Christiania. Besides introducing on the European market a great amount of American farm and other equipment, he invented a tile-laying machine which he exhibited at Bergen, Stockholm, and Paris. His particular interest in farm machinery continued, for during this period he invented a milking machine and several cream separators. In 1901 Holth returned to the United States and took work with the International Harvester Company of Chicago. While in Chicago he designed the self-balancing cream separator that bears his name and is the only one of its kind in present-day use.

With the restlessness of a Cleng Peerson, Holth again returned to Norway in 1916, intending to retire from industrial life. But in 1920 he was back in America, settling this time in southern California. One of his last inventions was a fish-trimming machine that he designed for the American Packing Company. He was interested in chemistry, and once went to

Canada on a mining expedition as engineer and chemical analyst. After this trip until his death in 1933, he gave most of his free time to chemical research, and during his last years he worked on atomic theory. He left a completed book, *Revolution in Physics and Chemistry,* and an unfinished manuscript dealing with his last theories on the subject of the atom.[1]

Most of Holth's many inventions have found their way into everyday American life—notably farming—but one must single out for special comment the plow on endless tracks. According to *Minneapolis tidende,* Holth was the first to employ the caterpillar principle.[2] The evidence would seem to support this statement. In 1885, while Holth was with the McCormick Company, he was asked to design a steam-driven tractor that could pull ten 16-inch plowshares. Because this machine was to weigh about 12 tons, it obviously would be unwise to put it on wheels, which would sink into the soft ground. To overcome this obstacle, Holth conceived the principle of the continuous track. *Minneapolis tidende* says: "At first he put one rail-chain in the middle of the machine and steered the plow with two wheels in front. Later he found that by using folding rails on both sides he could steer the machine by varying the speeds of the two caterpillar treads—exactly as is done in the modern tank." The letter patent of 1890 reads in part:

> The machine involves one or more steering-wheels at the front, a gang of plows at the rear, and a tractor or traction device arranged about midway of the length of the machine and comprising a wheeled engine-truck, which is jointed to the main frame of the machine, *and an endless slatted belt or track which passes about the truck-wheels, and which is so operated therefrom that during operation the truck-wheels will roll upon the endless slatted track and thereby be prevented from sinking into the ground.*[3]

The modern tank was developed for purely military purposes by British officers during the First World War. But the cater-

[1] For accounts of Anker Holth's life see Alstad, *Trondhjemsteknikernes matrikel,* 24; *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 21 (November, 1935); *Scandia,* April 7, 1938; *Skandinaven* (Chicago), April 25, 1933; and *Minneapolis tidende,* December 15, 1919, and April 20, 1933.

[2] December 15, 1919.

[3] U. S. patent number 437,759 (October 7, 1890). Italics are the present writer's.

pillar principle on which the tank operates was adopted from civilian use, and Holth was the first to utilize it for farm work. His tile-laying machine, designed in Norway, also exploited the principle of the endless track. Today the caterpillar tractor, utilizing the ideas of many men, is a vital part of civilian life — both rural and urban — and it is a fitting memorial to the skill of an immigrant engineer.

III

The arrival of the pioneer engineers coincided with a vigorous development in the American steel industry, and many Norwegians became associated with the production of steel and the design of structures using steel. One of the first of the group was Julius Aars Dyblie.[4]

Son of the sheriff and postmaster at Alten, Dyblie was educated first by a governess and then in the preparatory school of Hammerfest. He worked for a time in a blacksmith shop before entering and graduating from Trondhjem's Technical College. Subsequently, he was foreman of a London machine shop until he set out for America in 1879. He settled in Chicago and became a draftsman with the Joliet Steel Company, which was later purchased by the Illinois Steel Company, in turn a subsidiary of the giant United States Steel Corporation. When the plant shut down two years later, Dyblie was employed by the Calumet Iron and Steel Company at Irondale. He built a cut-nail factory at Hammond, Indiana; the Chicago Arc Light and Power Company's Plant; and later returned to the Joliet works of the Illinois Steel Company as master mechanic. During an interlude of seven years Dyblie was master mechanic with the Anaconda Copper Mining Company in Montana but he returned in 1899 to Joliet, where he served for twenty-nine years as chief of the steelworks there.

Dyblie's career was in many ways typical of those of a large

[4] See Alstad, *Trondhjemsteknikernes matrikel*, 346; *Norwegian-American Technical Journal*, vol. 10, no. 1, p. 7 (February, 1937), and vol. 3, no. 1, p. 16 (February, 1930); materials in the archives of the Norwegian-American Technical Society in Chicago; and *Skandinaven*, March 1, 1935.

number of the Norwegian engineers. It was distinguished by the efficiency of his plant direction and the remarkable originality of his mind. He patented many inventions for the steel industry which were widely adopted by the United States Steel Corporation and other companies.[5] The most important of his inventions was a reversing valve for heating furnaces, used today in blast furnaces all over America.

Dyblie's career was paralleled somewhat by that of Leonard Holmboe, who spent fifty-one years with the Illinois Steel Company.[6] Holmboe was reared in Christiania, where he also attended the local technical college. After graduation in 1879, he set out at once, despite strong family opposition, for America, and went immediately to Chicago. It is interesting that Olaf Hoff, later famed as a tunnel builder, sailed on the same ship.

Holmboe at first had difficulty finding work commensurate with his training and ability. In the fall of 1880, however, he took employment with the Illinois Steel Company, then called the North Chicago Rolling Mill Company. He remained with this firm until his retirement in 1931, becoming assistant chief engineer in 1889 and chief engineer in 1898. After retiring, Holmboe continued his technical work as a consulting engineer. He died in 1939, honored for his pioneer work in the development of steel.

Holmboe's hardships during his first year in Chicago evidently broadened his outlook and made him more than commonly sympathetic toward young arrivals. Rightly recognized for his limitless capacity for work and his engineering skill, he was also known for his patience and kindliness. "The Illinois Steel" became under his technical direction a distinct point of gravitation for migrating Norwegian engineers.

[5] Dyblie's patents cover a coke and ore barrows, a shutter worker, a clutch mechanism, a valve mechanism to provide "an improved three-way rotary valve the construction of which shall especially adapt it for use with the blowing-engines of metallurgical plants," a cock for controlling fluid under pressure, a cleaning door for hot blast stoves, and a windshield protector.

[6] For accounts of Holmboe's life see *Norwegian-American Technical Journal,* vol. 3, no. 1, p. 9, 15 (February, 1930); *Scandia,* March 16, 1939; *Skandinaven,* March 1, 1935, and March 17, 1939; *Minneapolis tidende,* March 17, 1939; and *Decorah-posten,* March 24, 1939.

The steel industry of the New World had another pioneer in Edward Holth, a farmer's son and a native of Kraakstad. A seaman for a time, Holth attended Horten and graduated in 1877. Two years later Holth set his course for Philadelphia, where he was employed by such firms as the Riehlé Brothers, William Sellers and Company, the G. V. Cresson Machine Shop, and the Pennsylvania Steel Company. He remained with the last firm for fifteen years as head of its designing department and as a mechanical engineer at the Steelton plant. He acquired considerable experience in the making of bridges and of steel rails, and in August, 1901, he became chief engineer of the Dominion Iron and Steel Company at Sydney, on Cape Breton Island. There he supervised the design and construction of an immense steel rail plant.

This steel mill was completed fourteen months after the order for the designing and drafting was given to the engineering department; this despite a strike at the general works and a severe winter which delayed freight service. The mill was called a "three high, three stands, 28″ mill," and the details of its construction were considered of sufficient interest to merit serious discussion in the *Canadian Engineer*.[7] The same journal quotes experts as saying that this was, in its day, "the best and handiest three-high-one-engine-mill, built anywhere." Operations began without the usual troubles that accompany the opening of new rolling mills. A "perfect rail was made from the first bloom rolled." Originally designed to roll about 1,000 tons per day, the mill soon "proved its capacity of turning out 1,200 tons every 24 hours; and this output could be maintained continuously if steel ingots could be supplied with the same regularity from their 10 open hearth furnaces; as for instance, from a Bessemer plant. As it is, the results are remarkable."

Holth left Cape Breton to return to Norway by way of Mexico, California, and the Orient. He was named by the Norwegian department of commerce a member of a committee

[7] Vol. 13, p. 38–43 (February, 1906).

working on the problem of electrometallurgy in Norway. He died in 1907.[8]

Of those early engineers who, like Holth, Dyblie, and Holmboe, centered in the Chicago area, Richard Mohn was the most significant in terms of structural engineering.[9] Though very little information about Mohn has reached print, it is known that he was born at Melsom, near Tønsberg, in 1856. In his early youth he attended private school and at nineteen he entered Christiania's Technical College. Mohn left after three years, went to Germany, and graduated from the Royal Polytechnicum at Dresden. He then sailed almost immediately to the New World, but later returned to Dresden for a special course in bridge engineering. More completely prepared for the American adventure, he went to Chicago in 1888, taking employment with A. Gottlieb and Company, a contracting firm.

In Chicago, Mohn not only designed and detailed bridges, but also worked on structural steel for the Masonic Temple on State Street (termed by some the world's first skyscraper), the Administration Building for the Columbian Exposition of 1893, and many other structures erected by his firm. The importance of his experience in this line can hardly be overemphasized. In 1894 he formed with J. Haakon Hoff, another Norwegian engineer, the firm of Mohn and Hoff. Though short-lived, this partnership did furnish and design the steelwork for Wicker Park Hall on North Avenue in Chicago and the Parrot Silver and Copper Company's smelter at Butte, Montana. They also furnished and erected the structural steel for the Cook County Jail on Dearborn Street, and acted as general contractors for the University of Illinois library building.

But Mohn was infected by the gold fever. In 1897 he became interested in the Klondike rush and, together with three younger argonauts, set out over the Edmonton Trail in search of riches.

[8] *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 140; *75 års biografisk jubileums-festskrift, Hortens tekniske skole,* 124; *Nordmands-forbundet,* 3:43–49 (August, 1909); *Morgenbladet* (Christiania), September 11, 1891; *Verdens gang* (Christiania), October 20, 1906; *Sydney* (Cape Breton) *Post,* January 27, 1906.

[9] *Norwegian-American Technical Journal,* vol. 2, no. 1, p. 16 (March, 1929).

He left Chicago in September; by the following February he was back, weakened by physical suffering and troubled with snow blindness. A trip to Norway seems to have restored his health. Upon his return he accepted a job with A. Bolter's Sons in Chicago, manufacturers of structural steel, and he represented this firm for a time in Kansas City. In Chicago again in 1906, he worked with the Illinois Steel Company. He died on January 29, 1907.

According to the *Journal* of the Norwegian-American Technical Society, Mohn introduced the H-shaped steel column used in modern buildings. This column was quickly adopted by Joachim Giaver and other structural engineers; it was cheaper to manufacture than were the box columns and Z-shaped bar columns that had been in common use. Mohn thought seriously of taking out a patent on the H-columns, but he failed to do so.[10] Had he succeeded in patenting his invention, it would have brought him the fortune he had sought in the Klondike, for his column, now universally adopted, has been used in a vast number of America's buildings.

J. Haakon Hoff, though less famous than his brother Olaf, is mentioned with respect by engineers who knew him and his work.[11] He was builder of no less than 18 bridges for the Chicago, Great Western Railway in the nineties and of most of the rolling mills for the famous steelworks at Gary, Indiana. Hoff was born in Christiania and graduated from the local technical college in 1888 with the degree of civil engineer. Haakon set his course for Minneapolis, where Olaf Hoff was then a consulting and contracting engineer. After some months in the employ of his brother, Haakon became a draftsman for the Milwaukee Bridge Company and later assistant chief engineer.

Seeking further experience, Hoff next joined A. Gottlieb and

[10] Vol. 2, no. 1, p. 16. There is reason to doubt that he could have patented the column even had he attempted to do so.

[11] *Norwegian-American Technical Journal,* vol. 1, no. 3, p. 5 (September, 1928), and vol. 2, no. 3, p. 5 (November, 1929); *Scandia,* April 7, 1938; *Skandinaven,* April 22, 1927; and Johs. Wong, *Norske utvandrere og forretningsdrivende i Amerika,* 194 (Oslo, [1925]).

Company in Chicago, who were then erecting the steel skeleton for the Masonic Temple. He worked on steel details from the beginning to the completion of this enormous structure, which covered half a block and, with its 21 stories, was for a time the world's tallest building. Hoff also participated in the construction of the Administration Building and of Machinery Hall at the Columbian Exposition. Before the fair opened, he returned to the Milwaukee Bridge Company as assistant chief engineer. He helped put up the structural steel for the courthouse, the first tall building in Milwaukee.

Hoff and Mohn no doubt became acquainted while working for Gottlieb, and their partnership was effected in 1894. As consulting engineers and contractors, they seem to have had sufficient work, but in 1897, when Mohn was struck by gold fever, Hoff entered into partnership with his brother Olaf. Hoff Brothers, located in Chicago, designed and rebuilt bridges for the Great Western Railway on the Chicago division and served as general contractors for this railroad's shops at Oelwein, Iowa.

In 1901 Haakon Hoff joined the American Bridge Company's western division in Chicago. First a contracting engineer, in 1906 he became engineer in charge of the designing and estimating department. The western division estimated nearly 50,000 tons of steel per month for office buildings and hotels, theaters, factories, mines, ore docks, and bridges. When Hoff died in 1929, the younger Norwegians lost one of their kindest supporters, the engineering profession a staunch champion who did much to further its interests, and his friends a charming and generous personality with artistic as well as technical talents.

Among the Norwegian engineers not many could lay claim to greater brilliance of intellect than Karl L. Lehmann; and few of this generally modest group were more self-effacing and reserved.[12] Born at Skjolden, in Sogn, Lehmann graduated from

[12] See *Norwegian-American Technical Journal,* vol. 2, no. 1, p. 15 (March, 1929); and *Skandinaven,* March 1, 1935.

Tank's School in Bergen at sixteen. The gifted student, already the pride of his teachers in preparatory school, then entered the Polytechnicum at Zurich, Switzerland. Before graduating as a civil engineer four years later, Lehmann served as assistant professor of higher mathematics and astronomy. He was also employed by the Swiss government in its geodetic survey. In 1882 he came to this country and worked for several years in the St. Paul bridge department.

Late in the 1880's Lehmann moved to Chicago and was employed in the bridge division of the city's engineering office. According to the *Norwegian-American Technical Journal,* Lehmann designed, at Cortland Street, the first trunnion bascule bridge built by the city that later became famous for its bridges.

The Columbian Exposition of 1893 drew heavily on the talents of many immigrant Norwegian engineers. Lehmann served as structural designer and attracted considerable attention by computing wind stresses in many of the fair's unusual structures. He also designed and patented a spiral tower some 200 feet in diameter and 600 feet in height. According to the plans, passengers were to be lifted on a specially constructed electric railroad to a spacious recreation pavilion at the top of the tower. This ingenious project, termed by newspapers "the eighth wonder of the world," was caught up by promoters; but despite their enthusiasm, they were unable to raise money in time to build the tower beyond the foundation stage.

For a while Lehmann was chief structural designer of the Chicago waterworks, but in 1914 he opened an office and established himself as a consulting engineer. He continued this independent course—one consistent with his nature—until his death in 1927. His clients were many, both in and out of Chicago, one of the largest being the Great Lakes Dredge and Dock Company. But Lehmann, for all his engineering genius, was no businessman. In this he was representative of the majority of Norwegian engineers who ventured to open offices. His reticence also prevented him from attaining the general recognition merited by his unusual skill, which won him the

reputation of a genius in steel construction circles. His close friends were amazed by his profound knowledge. They spoke, too, of his thoughtfulness and unselfishness in enabling others to benefit from his technical skill. But Lehmann was also independent to a fault and was characterized as much by his dislikes as by his likes. He left a number of talented and productive disciples who learned much about steel and bridge construction from their gifted teacher. Among these disciples was Thomas Pihlfeldt, who was later bridge engineer for the city of Chicago.

IV

Farther west, in Minneapolis, Carl Illstrup identified himself with the development of a great city's sewer system.[13] He was born in Drammen, where his father had a small shoe factory, and Illstrup attended the local Latin school before going to Christiania. In 1881 he completed the four-year course in civil engineering at the capital's technical college. Illstrup went directly to Minneapolis and after a brief experience with railroad building in northern Wisconsin, he entered the city's engineering office as a draftsman and instrument man in January, 1882. (Three other Norwegian engineers entered this department during the eighties, Nicolay Lund, Kris Oustad, and F. W. Cappelen.) Illstrup remained in the city's employ until his retirement on January 1, 1933 — a period of fifty-one years.

Minneapolis was little more than a good-sized town in the early 1880's, and Illstrup served in many capacities during his first years with the city. In 1885, however, he was appointed assistant sewer engineer, and in 1893 he became sewer engineer. Illstrup records that in 1882 Minneapolis had about one and

[13] Information for the following account was obtained from *Norwegian-American Technical Journal*, vol. 2, no. 3, p. 10 (November, 1929); an interview with Illstrup's daughter, Mrs. Walter Fuchs, of Douglas, Minnesota, in April, 1940; *Minneapolis tidende*, December 30, 1930, January 1, 1931, and December 22, 1932; *Skandinaven*, September 11, 1936, and July 7, 1939; *Minneapolis Journal*, October 8, 1909, June 25, 1919, January 3, and November 20, 1932; *Minneapolis Tribune*, February 24, 1929, May 27, and August 23, 1931; *Minneapolis Daily Star*, April 3, 1924, and January 15, 1927; and a part of the Illstrup papers graciously put at the writer's disposal by Mrs. Fuchs.

a half miles of sewer piping. When he retired in 1933 there were about 800 miles. His career therefore marked the virtual construction of the city's elaborate system of sanitary sewers, storm sewers, tunnels, and pumping stations, built at a cost of about $24,100,000.[14]

Describing the conditions he found when he began his services in Minneapolis, Illstrup later wrote:

> In 1882 we still were down in the old courthouse on Bridge Square. We didn't have money in those days to lay out a great system, but the engineers of the time saw to it that every necessity of the city was taken care of on the funds we did have. They built so that we could add additional sewers in an intelligent way, so that now 87 per cent of the city area has adequate sewer accommodations.
>
> In those early days sewer construction was a new work. There were few authorities on the subject, and most everything we did, we had to do by experiment, finding out by ourselves. The sewers were not large, compared to what we have today, but they were good ones. The biggest in the early days was a 44-inch sewer running along Washington Avenue S. and Hennepin.
>
> Much of the construction was carried on by hand; we had few machines. Dirt was thrown up from one scaffold to another, until it finally reached the top. There were no drilling machines, and we lacked the powers of electricity or compressed air to bore our tunnels. . . .
>
> We were thinking about a disposal system even 50 years ago. Every part of the system was laid out with that in mind.[15]

In 1919 the Minneapolis papers announced that Illstrup had drawn up plans for the largest, deepest, and most expensive sewer construction project ever outlined for the city. At a cost of $4,000,000, the new facilities would afford drainage for the rapidly growing southern portions of the seventh, twelfth, and thirteenth wards.[16]

In 1924 the same papers announced that the city's great sewer tunnel was almost completed. The first unit, begun three years earlier, was the Minnehaha tunnel, large enough to contain an electric railroad system and capable of carrying more

[14] *Minneapolis Journal,* January 3, 1932.
[15] *Minneapolis Journal,* January 3, 1932. See also the *Minneapolis Daily Star,* January 15, 1927, for an account of the discovery of a miniature underground lake.
[16] *Minneapolis Journal,* June 25, 1919.

water than the Mississippi. Three years of work 80 to 90 feet underground was required to finish this largest link in the sewer system for the southern part of the city. It extended northwest from a point on the Mississippi below Minnehaha Falls and Soldiers' Home to Forty-eighth Street, just east of the falls park. It was 5,510 feet long and at its largest part nearly 14 feet high and 10 feet wide. In addition to the electric railroad system, it also contained telephone and electric light systems, and a complete ventilation outfit that was installed as construction proceeded.[17]

Thus, under Illstrup's guidance, the modern sewer system of Minneapolis was developed and a disposal plant constructed. In 1931 Illstrup was talking of plans for a joint disposal project for both Minneapolis and St. Paul. "So well has the work in the past been done that the projected system ties into the old. The tunnels will connect up with a giant interceptor sewer which, in turn, will carry it to a huge plant for treatment."[18] The Minneapolis sewage disposal system, completed before Illstrup's retirement on January 1, 1933, was the object of considerable admiration.[19] Illstrup died six years after he retired.

Meanwhile, in St. Paul, O. I. Tolaas was pioneering in a different way with the Northern Pacific Railway.[20] Partly because of his work, the engineering offices of this railroad became a center for Norwegian draftsmen and engineers, where —as was also the case in the Minneapolis city engineering office—Norwegian could not fairly have been considered a foreign language.

Tolaas, whose father was a teacher, was born at Aarhagen, near Molde, in 1857. He attended grade school in the same town and he followed a precedent set by several of his family by entering Trondhjem's Technical College, from which he graduated in 1881 as a civil engineer. Soon afterward Tolaas left for America and for several years held various architectural

[17] *Minneapolis Daily Star,* April 3, 1924.
[18] Robert J. Fitzsimmons, in *Minneapolis Tribune,* August 23, 1931.
[19] Orlin Folwick, "Sewage Disposal," in *Minneapolis Tribune,* May 27, 1931.
[20] See Alstad, *Trondhjemsteknikernes matrikel,* 49; *Norwegian-American Technical Journal,* vol. 2, no. 3, p. 16 (November, 1929); and *Skandinaven,* December 8, 1939.

positions in Chicago and Minneapolis. In 1885 he began a long association with the Northern Pacific Railway Company at St. Paul. Except for a brief interval with the firm of Reed and Stem, of the same city, and a few years on his Wisconsin farm, he remained with the railroad until his retirement in 1928. What his work consisted of and how he met the challenge facing America's railroads have been tersely described by one who knew him well for many years:

> When I first met him, in 1901, he was Chief Designer of the Northern Pacific . . . and the variety of structures intrusted to him was appalling. Depots, bridges, coaling stations, roundhouses, shops, culverts, lunchrooms — no kind of equipment seemed to bother this man. He once confessed that many a time he has blessed Professor Carstens of the T.T.L. for the thorough training he gave him in mechanics, and Mr. Tolaas proved in his work that he was an honor to the Professor.
>
> A railroad engineering office of thirty years ago was quite different from those of the present day. A competent designer had to be at home in nearly every subject that enters into the physical parts of the road, locomotives and cars not excepted. He was crowded with work, and had no time to specialize, or as of late to devote his talents to special lines in which he might become a specialist. In such heterogeneous work Mr. Tolaas excelled. His keen and wiry mind and his knowledge of fundamental principles enabled him to turn from one problem to another with ready ease. The rapid development of the railroads caused the "permanent structure" idea to become a joke, and Mr. Tolaas several times tore down and rebuilt structures that when first designed were considered permanent. Under these conditions, no outstanding structure will remain as a memorial to the man's ability, but there are other monuments of greater value than skyscrapers.
>
> The influence of Mr. Tolaas' work will be felt in the engineering office of his employers for a long time to come; his helpfulness to "greenhorns," whether by nationality or from lack of theoretical and practical training, won him many a friend and helped in their future work. Those who had the opportunity to work with him for years will feel the effect of this association for the rest of their lives and will hold him in highest esteem.[21]

In 1909 Tolaas became chief architect for the entire Northern Pacific. In 1917 he retired to a farm at Long Lake in Wisconsin and the outdoor life that he loved. But three years later he re-

[21] R. A. Tanner, in *Norwegian-American Technical Journal*, vol. 2, no. 3, p. 16.

turned to his old office, where he remained until he again retired at seventy-one. Tolaas died in 1939.

St. Paul and the Northern Pacific claim yet another engineering pioneer in Størk Johan Bratager, who at the time of his retirement was assistant chief engineer of the railroad.[22] Bratager was born in Bergen, where his father was employed in the office of a malting firm. In Bergen he attended preliminary schools and the local technical college, from which he graduated in 1880. He then attended the Polytechnicum at Hanover, Germany. Returning in 1882 to Norway, he searched unsuccessfully for a position, and left for the New World in the spring of 1883. In New York he failed to find employment, and the Swedish-Norwegian consul advised him to go to Minneapolis.

Bratager was aware of the possibilities in railroad building, and shortly after his arrival in the Twin Cities he took a "temporary job" with the St. Paul and Pacific Railway Company, now a part of the Great Northern Railroad. This position lasted until his retirement in 1925. At first Bratager stayed in Minneapolis at a boarding club with other Norwegians — a common procedure among the engineers. He knew no English but, fortunately, had a chief with whom he could converse in German. From draftsman he was promoted to chief draftsman with the railway company. In 1893 he was transferred to the employ of the Northern Pacific Railway Company as chief draftsman, rising in the years that followed to assistant engineer, division engineer, office engineer, principal assistant engineer, and in 1923 to assistant chief engineer.

But his slow climb to the top of the engineering bureaucracy of a large railroad company tells little of Bratager's pioneer efforts. His technical achievements are also best described by another engineer:

[22] Information derived from American Society of Civil Engineers, *Transactions*, 95:1457 (1931); *Norwegian-American Technical Journal*, vol. 2, no. 3, p. 9; interview with Mrs. S. J. Bratager of St. Paul in February, 1940; *Festskrift ved Bergens tekniske skoles 25-aars jubilæum*, 52; *Minneapolis tidende*, September 4, 1930; and *Skandinaven*, September 9, 1930.

During his forty-two years of service Mr. Bratager was engaged in bringing the records and the physical condition of the railroad up to the high state of development which was required for taking care of the heavy traffic of 1925 as compared with the light traffic requirements of 1883. With a few assistants, he established the early distance schedules and records of the line, which due to the rapid growth of the system, had become an important and difficult problem. Later, when valuation work started, he made the first complete valuation of the railroad.

While Mr. Bratager's service was generally devoted to the design of engineering undertakings and office administration, he was greatly interested in the application of these designs. He was in charge of the construction of fifteen miles of the Sykeston Branch during 1899. His design of the steel rollers and screws used in the moving of the east pier of Bismarck Bridge proved very successful. This pier, with load, weighed 4700 tons, and was moved under traffic. On the completion of the work, it was found that 90% of the rollers had practically complete bearing after moving the pier.

During his long service with the Railway Company, Mr. Bratager gained the sympathy and confidence of his superiors, as well as the love and respect of his employees. All the engineers who received their early training under his direction will long remember him for his fair and correct dealings and his thorough investigation of the subjects at hand. His sympathy and help were of the greatest importance to all young engineers who, during his time with the Engineering Department . . . were looking for advice or a "start" with the Company.[23]

V

In the meantime engineers had begun careers in the industrial centers of the East as well as in the West. One of the earliest was Edwin Ruud.[24] As the inventor of household equipment that is now in universal use, he is well known to the many who are familiar with the products of the Ruud Manufacturing Company.

Ruud, the son of a farmer, was born in Askim County,

[23] Martin S. Grytbak, in American Society of Civil Engineers, *Transactions*, 95: 1457 (1931).

[24] Information on Ruud was derived from American Society of Mechanical Engineers, *Transactions*, vol. 55, record and index, p. 72 (1933); *Femti-aars jubilæumsfestskrift, Hortens tekniske skole*, 132; *75 års biografisk jubileums-festskrift, Hortens tekniske skole*, 117; *Norwegian-American Technical Journal*, vol. 4, no. 1, p. 2, 16 (April, 1931), and vol. 6, no. 1, p. 10 (April, 1933); *Minneapolis tidende*, December 15, 1932; *Nordmands-forbundet*, 17:426–428 (1924); and a portion of Ruud's correspondence in the possession of John H. Sorg of Pittsburgh, who also furnished valuable information in a personal interview.

where he received the usual elementary education. As the oldest son he should have taken over the family farm, but a pronounced mechanical bent led him to decide, with his parents' blessing, upon an engineering course. Graduated from Horten in 1876, Ruud was employed as a draftsman in Norway; he later went to Sweden, where he worked in Bergsund's Machine Shop in Stockholm. As a machinist he made the most of this opportunity to study machinery. He was particularly interested in American-made machines and machine tools and American manufacturing methods, already in use and in demand in Europe.

In the spring of 1880 Ruud left for the land of the machine. Like many another Norwegian engineer, his first job was in Philadelphia with William Sellers, a firm soon to make history in the machine tool industry. Like many another immigrant engineer, Ruud had no aversion to a lowly and dirty job. Eager to learn, he was put on the pay roll as a machinist and he worked in overalls.

Two years later he was employed by the Pennsylvania Railroad Company as draftsman in the engineering office of the engine and car building works at Altoona, one of the largest concerns of its kind in this country. There he was in an excellent position to learn railroading methods on one of the finest lines in North America. His work, however, was of a routine nature and made few allowances for his originality or creative spirit. Having mastered the railroad routine, and finding his health none too good, he returned to Norway in the summer of 1884, accompanied by Edward Holth.

But the tempo of American industrial life had entered Ruud's nervous system. In 1885 he was back in Pennsylvania, this time with the Reading Iron Works. This position, like the others, broadened his general knowledge of engineering and production and prepared him for his work with George Westinghouse in Pittsburgh, which began in 1887. Westinghouse, himself an inventive genius, saw in Ruud a kindred spirit sensitive to the crying needs of a new era. For Ruud, Westinghouse opened

the gate to a new existence for which, unconsciously, he had been preparing himself since his arrival in the United States. In this existence ideas counted for everything and dull routine played no part.

The story of Ruud's career in America is the story of the machine in its relation to gas. In the latter part of the 1880's engineers were developing producer gas machines. Experiments had advanced to the point where it seemed feasible to make a machine capable of producing inexpensive gas fuel for communities and industries. The great abundance of cheap coal in America seemed a guarantee of adequate raw material, and in the New World no machine, however fantastic, was impossible. George Westinghouse's fertile mind began to visualize a great new industry, and his first step toward its realization was the creation of the Fuel Gas and Electric Engineering Company. Ruud was assigned to this firm and he collaborated with Westinghouse in developing the producer gas machine. But the Norwegian's inventive genius, now given free play, simultaneously helped bring into being a series of gas-consuming appliances for home and factory. These included ranges, automatic water distillers, room heaters, and industrial apparatus of various kinds. Among Ruud's inventions was the automatic water heater, first manufactured in 1888–89 and patented in 1890–91.

The producer gas machine, in which Westinghouse had placed much faith, failed to measure up to its early promises. The Fuel Gas and Electric Engineering Company, however—thanks to Ruud—had perfected enough appliances to keep the firm alive for a number of years, and after that it was reorganized as the Pittsburgh Meter Company. The basic reason for the failure of the gas machine was the utilization in the late eighties of the large supply of natural gas in the oil region of western Pennsylvania. Engineers in Pittsburgh became interested in the possibilities of this cheap, pure fuel and its employment in distant cities. George Westinghouse characteristically threw himself into this enterprise.

Two phases of the natural gas problem interested Westing-

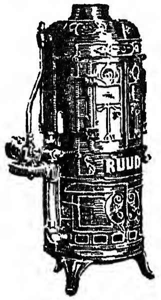
house most. The first had to do with measuring the flow of gas from a well. Since the volume of gas ran into millions of cubic feet daily and its pressure was several hundred pounds per square inch, it would obviously be difficult and costly to build a meter through which all the gas was to flow. What was needed and what engineers were trying to develop was a proportional meter; that is, one through which only a small part of the gas would pass but which nevertheless measured accurately the total flow. Ruud developed one of the first accurate proportional meters.

The second project in Westinghouse's mind was the gas engine, which he conceived of as a prime mover of the future. He set Ruud to the task of developing this engine. The finished product was considered the foremost in its field. For a time it was widely used, but it had to give way to the steam turbines and turbo-generators that later came into general use. Working with the gas engine was of inestimable value to Ruud in that it brought him into close contact with Westinghouse. The two men traveled together in Europe in search of new ideas and better engineering methods. Ruud not only had a stimulating relationship with his friend and employer but also met and worked with many great Europeans: Rudolph Diesel, inventor of the famous Diesel engine; Dr. Walter Nernst, who developed the Nernst lamp; Lord Kelvin, the great English physicist; and Emil and Walter Rathenau, of the German dye industry — the latter famous in the First World War and postwar years as German economic director and social philosopher. European business contacts, made through the British and French Westinghouse companies, were also to be of value in Ruud's later years.

Ruud's reputation, however, was destined to be based — and not with absolute justice — on the automatic gas water heater.[25] He had invented the heater and also an automatic water dis-

[25] Patent numbers 443,797, water heater (December 30, 1890); 460,513, water heater (September 29, 1891); 610,281, automatic water heater (September 6, 1898), "an automatic water-tube or coil-heater in which the supply of heat is regulated by variations in the temperature of the water in the heating-coil."

tiller while employed by the Fuel Gas and Electric Engineering Company. Because of the failure of the producer gas machine, neither device was at first a great success, but Ruud was confident of a large potential market for his inventions. Westinghouse had never pushed the gas heater, believing that the ordinary householder would be unwilling to tear out his old tubs to make room for the new appliance. Ruud therefore was able to buy for $380 the patents that had been taken out in his name but assigned to the Westinghouse companies. In this he was more fortunate than other Norwegian engineer-inventors.



Ruud Automatic Gas Water Heater

In collaboration with James Hay, a plumber, Ruud began a business venture in a shack on Pittsburgh's north side. He improved his appliances and began to sell them on the American market. His first heater, built in 1895, was given the trade name Pittsburgh Water Heater. Two years later the Ruud Manufacturing Company was organized; it offered two kinds of heaters — the instantaneous automatic water heater and the automatic storage type. Both were designed to use natural gas, but in 1902 Ruud perfected improvements which made them suitable for use with manufactured gas. During the next two years a sales force and branch offices in many large cities of the United States and Canada were organized. Many new inventions followed to make the Ruud heater suitable for varied needs, and the business, modestly begun, grew into a widely respected firm.

Despite Ruud's manufacturing project, he had continued his association with Westinghouse. In 1903 he resigned from active duty with the various Westinghouse companies, pleading ill health as the cause.[26] George Westinghouse's answer to the resignation is revealing; he deplored Ruud's decision to retire and asked for the privilege of calling on him from time to time

[26] Edwin Ruud to George Westinghouse, September 25, 1903, Ruud correspondence.

for limited services if his health and his other duties permitted. He added, characteristically:

> I appreciate what you say in regard to our relations. They have always been of a most pleasant character to me and I have appreciated your work, as you have had occasion to know so many times.
>
> The gas engines which have been developed since we took up the business seem to be superior to any others on the market; but, as you also know, I do not think we have gone ahead as fast with the large engine work as we should have done. . . . I have, however, determined upon a course which will lead to a much more rapid development of the gas engine work, and it is in connection with such development that I may now and then wish to have your advice.[27]

As the Ruud Manufacturing Company grew in size and its output increased, Ruud, a heavy shareholder in the company, became a man of considerable means. In addition to the plant at Pittsburgh, factories in Michigan, Texas, and California turned out his products. For the European market a factory was maintained in Hamburg, and offices were opened in Berlin and London. Before Ruud's death on December 10, 1932, he had the satisfaction of knowing that his products were widely adopted by Europeans and Americans alike.

VI

> Up to about 1500 there were, and had been for two thousand years, only two basic forms of construction; the post and lintel as used, for instance, in the Parthenon, and the arch with its derivatives, the vault and dome as used . . . in St. Peter's in Rome. Along towards the end of the fifteenth century the true truss, composed of members some of which are in compression and some in tension, was invented. That was the third. And now in our era we have added a fourth—reënforced concrete.[28]

By anyone at all familiar with modern construction materials, reinforced concrete is recognized as an absolutely vital element, whether for skyscrapers, paving, viaducts, grain elevators, bridges, fortifications, or the dozens of other uses that

[27] George Westinghouse to Edwin Ruud, September 25, 1903, Ruud correspondence.

[28] Thomas E. Tallmadge, *The Story of Architecture in America*, 282 (New York, 1936).

have been found for the material. According to a guarded report of a committee of the American Society of Civil Engineers in 1916, the "adaptability of concrete and reinforced concrete for engineering structures or parts thereof, is so well established that they are recognized materials of construction." It continues: "By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in various structures and structural forms. This combination of concrete and metal is particularly advantageous in structural members subject to both compression and tension, and in columns where, although the main stresses are compressive, there is also cross-bending."[29]

It follows that anyone vitally connected with the development of reinforced concrete in the last half century merits considerable notice. The man who did as much as anyone to introduce it in America and to help it through its early stages is Eyvind Lee (Lie) Heidenreich, born on Stord Island, near Bergen, in 1860.[30]

Heidenreich's father was a district judge and his mother a sister of Jonas Lie, the novelist. He had private tutoring on the island and public schooling at Flekkefjord, and then enrolled at Trondhjem's Technical College. He was graduated with degrees in both mechanical and civil engineering in 1880, and went directly, not to America, but to Russia. There he was employed by the Nobel brothers in their Baku oil department. In Russia Heidenreich learned Russian and Polish and perfected his knowledge of French and German—languages that stood him in good stead later. His Russian period, however, was a short one, for in the next year he set out on the now familiar

[29] "Final Report of the Joint Committee on Concrete and Reinforced Concrete," in *Proceedings*, 42:1657–1708 (December, 1916). It is interesting to note that Olaf Hoff was a member of this committee. The quotation given is to be found on page 1665.

[30] Considerable information obtained directly from Heidenreich has been woven into the following account. Important facts were also found in Alstad, *Trondhjemsteknikernes matrikel*, 28; Alstad, *Tillegg*, 18; *Who's Who in Engineering, a Biographical Dictionary of the Engineering Profession, 1931*, 580 (New York, 1931); *Norwegian-American Technical Journal*, vol. 3, no. 1, p. 9 (February, 1930); and *Scandia*, April 7, 1938.

course to America. He was eager to learn modern engineering as it is practiced in the New World and to earn an adequate living, but, like others of his countrymen, he planned to return one day to Norway.

On June 26, 1881, Heidenreich, accompanied by a Russian friend, landed in New York, and with other immigrants left at once for Chicago. His enthusiasm for America, aroused by New York's tall buildings, elevated railroads, and the Brooklyn Bridge, continued to mount when he found a position on the day of his arrival in Chicago. His job, as a machinist's helper in a sewing machine shop, paid him only $3.50 a week and held no promise for the future. After two weeks in Chicago he became a draftsman for the Illinois Steel Company at Joliet, where he remained three and a half years and was earning eventually the unheard-of salary of $75 a month. Among his earliest engineering experiences was designing the first 10-ton crane and ladle for Bessemer Steel; he also took part in the design of a 10-ton steel converter.

Heidenreich resigned to become a structural engineer for the Lambert and Bishop Wire Fence Company in Joliet and built their first wire mill. In 1884 he returned to Chicago, where he took work with an architectural firm, and designed three large churches. He next accepted a position with J. A. McLennan, grain elevator contractor. Becoming interested in elevators, Heidenreich left McLennan in 1889 and started his own business as contracting engineer. In 1890 he reorganized this firm as the Heidenreich Company, Engineers and Contractors; his brother, S. Lie Heidenreich, and a college mate, Harold Boedtker, were his partners. Contracts were signed for grain elevators, manufacturing plants, eleven of the buildings for the Columbian Exposition, two sections of the Chicago drainage canal, some railroad work, and government docks and piers.

At the exposition in 1893 Heidenreich, doubtless because of his linguistic abilities, was named chairman of the committee assigned to receive foreign engineers. In this capacity he met Hermann O. Schlawe, who had been sent from Rumania

to study American grain elevators.[31] Schlawe, who spoke German, was enthusiastic about the Monier constructions then becoming popular in Europe and gave Heidenreich some books explaining them. The result was that Heidenreich became an able disciple of Monier and began a crusade to introduce his system into America.

It should be explained that the Frenchman J. Monier (1823–1906) is generally credited with the invention of reinforced concrete. Though not the first to use a combination of iron and cement, Monier "was the first to combine them scientifically, so that they supplemented each other and acted as a single unit of material." Since he was interested in gardening, his first patent, dated July 16, 1867, covered the building of tubs, flowerpots, reservoirs, fountains, and basins in which wire netting was imbedded in the cement. In this way Monier was able to "secure lightness without sacrificing strength." Later he applied his invention to railroad sleeping cars, floors, buildings, footbridges, gas and water tanks, and arches, and covered these with patents.[32] G. A. Wayss of Berlin obtained in 1880 the patent rights for Germany, Austria, and Russia and formed a central technical bureau in Berlin with branches all over Europe. He systematically applied the Monier method to houses, bridges, and hydraulic work, as well as to reservoirs, and in 1887 wrote a book called *Das System Monier*. This work created no little stir among engineers. One result was that the royal architect in Berlin, a Herr Koenen, aided the system by theoretically proving the stability of the new material and developing mathematical formulas for making calculations.[33]

[31] This common interest brought the two men together, for Heidenreich delivered an address before an international gathering of engineers at the exposition on the subject "American Grain Elevators." Printed in American Society of Civil Engineers, *Transactions*, 29: 644–652 (September, 1893), this speech was a resumé of the progress made up to that time in constructing American grain elevators.

[32] Richard Shelton Kirby and Philip Gustave Laurson, *The Early Years of Modern Civil Engineering*, 273 (New Haven, 1932); published by the Yale University Press. A good early history of reinforced concrete is Paul Christophe, *Le béton armé et ses applications* (Paris and Liége, 1902).

[33] E. Lee Heidenreich, "Armored Concrete Constructions," in *Cement and Engineering News*, 14: 36–39 (March, 1903); and E. Lee Heidenreich, "Monier Constructions," in Western Society of Engineers, *Journal*, 5: 208–224 (June, 1900).

In the perfected Monier system round bars were crossed at right angles, making a trellis-like effect. The purpose was to strengthen the cement by placing the rods in such a position that they would assume the main tension or compression stresses.

A great number of variations in reinforced concrete developed after Monier, but the Monier patents were so broad, Heidenreich maintained, that they embraced in general any iron parts encased in cement. As the sole representative in America of Monier construction, Heidenreich naturally was motivated in his career by a strong element of self-interest. He organized a central technical bureau of Monier constructions at Chicago, a northern bureau at Minneapolis (with F. W. Cappelen), an eastern bureau at Buffalo, a southern bureau at New Orleans, and a Pacific bureau at Los Angeles, to exploit the Monier methods developed by the Germans and to guard against infringement on patents. In his business, too, he gave tangible evidence of his new interest by building the first reinforced-concrete tank in the Illinois Steel Company's Chicago yards and a cement storage elevator for the same concern.[34]

Of greater importance were his personal innovations in the field of reinforced concrete construction, especially a fireproof grain elevator, patented in 1901. He also patented a fireproof roof and the Lee corrugated bar, which replaced the smooth rods used by Monier and was extensively adopted for concrete work in America.

As a propagandist for Monier constructions, Heidenreich let pass no opportunity to present his cause before engineer groups and in technical periodicals. Some of his articles and speeches constitute a species of pioneering and are as interesting as they are significant. Speaking before the Western Society of Engineers in Chicago on June 6, 1900, he explained that Monier constructions, almost unknown in this country a few years earlier, were finding a steadily increasing appli-

[34] "Monier Cement Storage Elevator at South Chicago," in *Cement and Engineering News,* 13:88 (June, 1902).

cation in all branches of engineering. With an "unexpected increase in the cost of material and manufacture of steel structures, fortified concrete constructions have gradually attracted attention as a substitute for steel, and are, at present, approaching a universal recognition, also, in the United States." Iron imbedded in cement, he explained, is virtually rust-free. In outlining some of the uses of reinforced concrete, he mentioned, first of all, reservoirs for water, wine, oil, pulp, grain, and cement.

Reinforced concrete is used also for bridges and viaducts, walls, floors, and partitions, culverts and flumes, fortifications, as in Germany and Austria, bombproof vaults, and canals. The general advantages of Monier constructions were listed as durability, proof against fire, maximum carrying capacity with a minimum of weight, resistance against shocks and vibrations, economy of space, rapidity of construction, cleanliness and absence of organic matter, economy, resistance to air and water, dryness, adaptability to all possible forms or shapes, safety against thieves and enemies, and reduction in insurance rates.[35]

Several years later Heidenreich published in serial form a somewhat elaborate study of "Armored Concrete Construction."[36] This was a comprehensive account, largely technical. The study revealed, however, that while the original Monier patents were of small value and had for years been "public property abroad," the later patents still had "some six years to run in the United States." Heidenreich's exclusive right to use Monier constructions was therefore definitely limited in time. New uses of reinforced concrete were also cited: in beams, girders, foundations, pipes, sewers, stairs, grandstands, chimneys, fence posts, smokestacks, and—adding a note of finality—coffins.

A third, briefer presentation of the case for Monier was made by Heidenreich in the *Railway and Engineering Review.*

[35] Western Society of Engineers, *Journal,* 5:217–224 (June, 1900). See also the supplement to the same discussion, 5:329–339 (October, 1900).

[36] In *Cement and Engineering News,* 14:36–39, 55–60, 75–84, 107–112 (March–June, 1903); 15:3–13, 27–35, 51–58, 76–82, 100–109, 124–136 (July–December, 1903); 16:156–160, 180–184, 204–208, 228–237 (January–April, 1904).

During 1896–97, he maintained, the "clamor for fire-proof construction became more and more pronounced every day; in grain elevator construction, for instance, steel tanks commenced taking the place of the stereotyped wood-bin construction; concrete and tile floors were replacing the then modern mill construction for factories, and without noticing the change the engineering and building fraternity slowly saw the age of steel and iron wane before the age of cement and concrete." [37]

Instances in which Monier constructions were used tell a graphic story of the introduction of the new building material in America. F. H. Peavey and Company of Minneapolis built a grain storage elevator in Duluth of "some three and a half million bushels capacity, entirely in this fortified concrete construction," as a result of Heidenreich's representations to Peavey. The Illinois Steel Company in Chicago had the casting floors in front of their new blast furnaces built in the Monier construction. In Buffalo, New York, the commission of grade crossings specified the new product for "both the roadbed and sidewalks for the Louisiana Street viaduct and the Elk Street viaduct, giving the Monier constructions an important impetus in municipal work."

At the turn of the century the Illinois Central Railroad asked Heidenreich to put in a culvert near Baton Rouge, Louisiana. "The embankment slid out, but to the surprise of everyone concerned, the Monier culvert withstood all twisting and displacement, and is still intact." [38] The Canadian Pacific grain elevator at Port Arthur, Ontario, built on Heidenreich's cluster-tank principle with nine tanks, was, naturally, of reinforced concrete; in the early years of the twentieth century, elevators built of this material gradually replaced large wooden structures at terminal points. Literally hundreds of concrete elevators were built in Canada and the United States; their capacities ranged from 50,000 to 4,000,000 bushels.[39] In 1902 Heidenreich planned

[37] Vol. 42, p. 165 (March 15, 1902).

[38] These projects are listed in *Railway and Engineering Review*, 42: 165.

[39] Heidenreich, *Pocketbook of Reinforced Concrete*, 382–389 (1915). The author makes it clear that there was little literature on the designing of grain elevators and other storage structures. Such work requires, he says, a practical knowledge not gen-

and specified the first Monier viaduct in America at Santa Monica, California. This had two 67-foot spans and as late as 1915 was the lightest Monier viaduct in America. In Germany, Switzerland, and France, however, reinforced concrete bridges of even lighter construction could be found.[40]

Heidenreich's last and most effective plea for concrete was his *Engineers' Pocketbook of Reinforced Concrete,* published in New York in 1908. The result of fifteen years given largely to the study and use of the new material, this book soon became a standard work and was revised seven years later. He explained in the preface that since the publication of an earlier work, *Monier Constructions,* reinforced concrete had "made such gigantic strides forward, that it has entered every branch of civil engineering." He stated that the American Society for Testing Materials and the American Society of Civil Engineers, through a joint committee of which Heidenreich was a member, were trying "to standardize specifications and to recommend factors and formulas 'required in the design of structures in which this material is used.' As yet the committee has not attained results further than 'a knowledge of the work such a report demands.' " In the meantime he had been "writing, changing, substituting, and improving the book for upwards of eight years," and finally let go of it "for his own peace of mind."

From 1901 to 1905 Heidenreich spent much time in traveling about the country, designing reinforced concrete structures. In 1905 he was employed as a special engineer by the New York Central Railroad while it changed its Hudson division from steam to electric power. In 1911 he resumed work with the Heidenreich engineering company, and he moved its head office to Kansas City in 1914. There he was given charge of the revision of the building code and was also put on a committee to appraise the metropolitan railroad. But he continued to work with reinforced concrete, to build grain elevators, to lecture, and even to give instruction to young men in the proper

erally possessed by engineers. Heidenreich was the first to design reinforced concrete grain elevators in America.

[40] Heidenreich, *Pocketbook of Reinforced Concrete,* 292–295.

use of concrete. During the First World War he designed ships and fuel oil tanks in concrete, as well as mills, elevators, and bridges. Later he planned grain elevators in Sweden, an oil refinery in Italy, and fuel tanks in Norway.

His inventive ability unimpaired, Heidenreich designed a piping system for concrete ships and tankers in 1918. As late as 1921 he was commenting in a technical journal on the gondola railroad cars of reinforced concrete used in central Europe, and on concrete farm silos and skyscrapers in Germany.[41] Later in the same year he came out characteristically in support of the oil storage tanks which he had perfected during the preceding decade. Little or no advance, he argued, had been made in the ports where the bulk of our oil is put in motor ships. The steel fueling structures along the coast had definite shortcomings. Heidenreich had experimented with oil storage off and on since he was with Nobel forty years earlier, and had "finally succeeded in building oil-proof storage."[42]

In later years his mind turned to more theoretical studies. In 1924 he published an analysis of *Reuterdahl's Synthesis;* this was followed by *Reuterdahl's Light Quantum Theory* in 1929. A number of other monographs have also come from his vigorous pen.[43] Though making a lively hobby of subatomic research, he did not entirely forget reinforced concrete after his retirement to Santa Monica, California. He experienced the satisfaction of one who, having found something good in the Old World, lived to see its adoption in the New.

VII

Bernt Berger, unlike Heidenreich, was identified with no specific development to which his name can be clearly linked in history, except general structural work.[44] Nevertheless, he was

[41] *Concrete,* 18:247–249 (May, 1921).

[42] *Concrete,* 19:222–225 (December, 1921).

[43] They include *Relativity; The Constant Velocity of Light; The Constancy of Concrete;* and *Pumicite.* This information was furnished by Heidenreich.

[44] Alstad, *Trondhjemsteknikernes matrikel,* 57; *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 10, 12 (July, 1929); *Minneapolis tidende,* January 27, 1919; memoir by Frank W. Skinner in American Society of Civil Engineers, *Transactions,* 83:2355 (1919–20).

one of the ablest of Norwegian engineers in America. In this he is representative of a large number of men who, as superb engineers, were called upon to use their talents in a variety of structural tasks.

Berger, the son of a ship captain, was born at Drammen. He completed the course in mechanical engineering at Trondhjem's Technical College in 1885, and spent a year in the Drammen city engineer's office before his departure for America. When he arrived in New York in September, 1886, he entered the employ of Theodore Cooper, widely known consulting bridge engineer. This association continued until Cooper's death in 1908; and Berger then succeeded to the consulting practice.

Berger became known for his accuracy and for his sound methods of investigating and handling technical questions, particularly difficult structural problems. He quickly won the confidence of Cooper and his clients and was put in charge of many reports, investigations, and designs. More and more he tended to specialize in long-span steel bridges, concrete arch spans, reinforced concrete, substructure work, and general steel construction. He was recognized as a leading authority on steel structures and a specialist in bridges. His knowledge of steel also made him sought after by subway contractors. He played a significant part in the building of the great Quebec Bridge, the New York Public Library building, the New York elevated railroad structures, and innumerable railroad bridges, in South America and Japan as well as in the United States. As a specialist in inspections and recommendations for the safety of existing structures, he gave help to other engineers, contractors, and architects who sought his advice. He put his stamp of approval, among other projects, on the steelwork in several sections of New York's subway system.

Outstanding when measured by a technical yardstick, Berger won a second reputation among Norwegians for his helpfulness to young engineers. Apparently free of the restlessness so common in his profession, he remained in the New York area until his premature death. He developed into a kind of permanent

point of contact for Trondhjem's graduates who sought positions in America. Many stories are told of his generosity, his kindly hand, and his encouraging words. One at least is worth recounting:

> In the early days, when he worked for Theodore Cooper, Berger was not always in the office when some of these new arrivals called. . . . Mr. Cooper sometimes had a hard time explaining when Berger would be back. Mr. Cooper then would ask: "Trondhjem?" And if they said yes, he would take up his watch and explain by pointing with the finger to the hour at which Mr. Berger would return. Mr. Berger was of a very kind disposition, and his purse always was open to help provide the necessities of struggling young engineers and students who had arrived from abroad with only a few friends and no experience in this country. He had a hearty, affectionate nature that endeared him to his friends beyond the ordinary, and his sympathetic actions and manner always will be remembered with pleasure.[45]

Despite the heavy drain imposed on Berger's time and energy by his technical duties, his studies, and his literary interests, he also served in an amazingly large number of organizations, charitable and social as well as technical. The fact that he was unmarried and therefore did not have the many diversions that are a part of family life is only a partial explanation of his amazing breadth of activity. A hard worker, he also loved food and drink in the company of good friends. He died in 1919, at the height of his career, not yet fifty-three, thus depriving his adopted country of one of its leading technicians and the younger engineers of a true friend.

It would have been strange indeed if none of a group of emigrant engineers who represented a seafaring people had pioneered in the world of ships. Henrik Lysholm earned an enviable reputation in American shipbuilding circles.[46] He might with some justice be called the Henry Ford of the shipyards. Lysholm was the son of a captain who had charge of the Carl Johan navy yard at Horten. After attending Trondhjem's Technical

[45] *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 10.

[46] Alstad, *Trondhjemsteknikernes matrikel,* 356; *Sjøfartstid,* a Norwegian publication quoted in Alstad, *Tillegg,* 105–107; *Minneapolis tidende,* October 12, 1921, and January 29, 1922.

College, he worked for a time at the Horten navy yard with special emphasis on the study of shipbuilding. In 1887, at the age of twenty-one, he migrated to America in search of technical knowledge and experience. His search brought him employment in many workshops as draftsman, chief draftsman, and foreman. In 1889 he became general superintendent for the New York Shipbuilding Company. For a short time he had maintained, with Carl Wigtel, a ship engineering firm in New York. While working as an engineer with Hollingsworth's in Wilmington, Delaware, he learned the arts employed in bridge construction. Later, during the early years of the New York Shipbuilding Company, he applied these techniques with infinite skill to the building of ships.

The New York Shipbuilding Company, with its model yards at Camden, New Jersey—just across the Delaware River from Philadelphia—was in many respects unique; its ships were built, however, on two major principles adopted by Lysholm.[47] First, all materials going into a ship were conveyed in one direction from the storeroom to the various departments where ribs, keel beams, and deck pieces were made. These parts went to a general assembling department, where they were riveted together into sections, so far as their construction permitted. The sections were then hoisted by cranes onto the ship's ways. With this system Lysholm eliminated repeated carrying and lifting, with their attendant waste of motion and time. The other principle involved something of a revolution in the shipbuilding trade. Parts going into a ship were, in so far as possible, standardized and marked for assembling. The application of these principles necessitated a large and competently managed mold loft and a separate division in the steel plate shop, the "laying-out" department. These two departments were Lysholm's favorites and the workers knew it. When his tall, broad-shouldered figure came walking through, one of them would say, "That's him! The grand old Norwegian!" Called by his workers the "Old Man," he was warmly admired and respected.

[47] According to *Sjøfartstid*, quoted in *Tillegg*, 105–107.

Lysholm's influence was also felt in methods of fabrication. He experimented with punching and drilling and in 1916 produced the Lysholm punch machine. This machine eliminated the work of at least two men and increased greatly the number of holes punched per hour.

In the spring of 1916 Lysholm took part in the launching of the Christoffer Hannevig[48] shipyards at Gloucester, New Jersey. He was confronted by so many problems while there that he overexerted himself. His work with Hannevig resulted in at least one important innovation: the sideways launching of 7,000-ton tank ships, a feat considered impossible until Lysholm performed it. He later established a consulting office in Philadelphia, no longer having the necessary strength to superintend the work of the two shipyards at Camden and Gloucester. But when, during the First World War, our government decided to build 32 torpedo boats at the New York Shipbuilding Company, Lysholm was called to organize the work. He continued active until he died prematurely in 1921. At the time of his death he was working on what promised to be an epoch-making arrangement for unloading ships. Authorities, it is reported, were eagerly awaiting its completion.

The last in this series of representative pioneer engineers is Carl Wigtel, known for his inventions and general mechanical genius.[49] Magnus Bjørndal states in the *Norwegian-American Technical Journal* that when the history of the development of the American machine age after 1887 is written, an important section must be devoted to Wigtel, vice-president and chief engineer of the Watson Stillman Company, manufacturers of special and hydraulic machinery.

Wigtel was born at Stenkjær in 1862. He finished the local public school, and at seventeen went to work as an apprentice in a Trondhjem machine shop. In the late 1870's Norway was

[48] For an account of this interesting Norwegian shipping magnate, see A. N. Rygg, *Norwegians in New York, 1825–1925,* 177–180 (Brooklyn, 1941).

[49] See *Norwegian-American Technical Journal,* vol. 4, no. 1, p. 13 (April, 1931), and vol. 6, no. 1, p. 10; Wong, *Norske utvandrere,* 70; *75 års biografisk jubileumsfestskrift, Hortens tekniske skole,* 148; *Skandinaven,* June 3, 1927; and *Nordisk tidende* (Brooklyn), April 29, 1926.

changing over from the English system of weights and measurements to the metric system. Wigtel's employers had the concession to complete this undertaking in the entire northern part of the country, and the young apprentice was put to work repairing, adjusting, and making scales. At the age of twenty-one, Wigtel set out for England, where many Norwegians were working as apprentices, and promptly found employment in Hull as a full-fledged machinist earning 30 shillings a week.

His experience in England only whetted Wigtel's thirst for knowledge. After one year at what was then a more than respectable income, he returned to Norway. He attended Horten's Technical School during 1885–86 and graduated at the head of his class despite earlier difficulties in mathematics. For the next few months he had a temporary job as draftsman in the Trondhjem machine shops. But economic conditions at home were unfavorable, and he emigrated to America in 1887. He arrived in New York at six in the evening of March 30; at ten o'clock the next morning he had a position with the C. W. Hunt Company on Staten Island as draftsman. After six months with this firm, he joined the Watson Stillman Company as its first draftsman. For forty-two years Wigtel was connected with this company, rising from draftsman to chief draftsman, to director, and then to vice-president and chief engineer.

During his long career with Watson Stillman, Wigtel designed the hydraulic machinery required for the construction of all the tunnels, except the Holland Tunnel, under the Hudson and East rivers in New York City, and the hydraulic machinery used in building the Boston and Baltimore subways.

The Watson Stillman Co. built all kinds of special machinery, and there never was a job too large or too difficult for Mr. Wigtel. He developed the first large presses in the United States for the extrusion of copper and brass bars, as well as for drawing seamless tubing. He designed giant hydraulic presses for special purposes in the steel industry, for the making of projectiles, etc., and he was a pioneer in the development of high-speed hydraulic presses for the manufacture of pressed steel articles. Presses designed by Mr. Wigtel range in size from 10 to 4,000 tons. The inventor of the famous steel pulley, manufactured by the American Pulley Co., once came

to Mr. Wigtel and wanted him to design a press to make three pulley rims per minute, but when the press was put in operation, it actually produced eight to nine per minute. Pulleys made from these presses are today turning the wheels of the world. Similar results were obtained with presses for making phonograph records. While originally it required three minutes to make a record, Mr. Wigtel designed a semiautomatic press that made them in 45 seconds, and some of these presses eventually were exported to many different countries. Another interesting design was a large four-pressure automatic hydraulic valve which Mr. Wigtel, in 1901, designed for a large steel concern, and which, thirty years later, is still working and giving the same satisfactory service as when new.

During the war Mr. Wigtel was busily engaged making many kinds of hydraulic machinery required by manufacturers of ammunition and ordnance. He also designed much special machinery for the ammonia plant erected . . . at Sheffield, Ala.

At one time during the war Mr. Wigtel was asked to bid on 10,000 hydraulic jacks to be used to lift heavy ordnance in the field. Practically all ordnance was then manufactured from French designs, but Mr. Wigtel did not like the design of the French jack, so he refused to bid on it, but designed a new one, the drawings for which he took to Washington and submitted to the French officers in command. They were so well pleased that they not only approved his design, but decided that his was so much better than the French jack that he immediately got the order, totalling more than one and a half million dollars, his bid being $350,000 lower than the lowest bid on the French jacks. Mr. Wigtel holds more than thirty patents which he has obtained on his many special machines.[50]

Among Wigtel's many inventions was a hydraulic apparatus for hoisting the center span of the Quebec Bridge; this span weighed about 5,500 tons. Wigtel is also known for an automatic valve used under high-pressure conditions. He died in 1933.

VIII

The story thus recounted might suggest that all of the emigrant engineers were satisfied with conditions as they found them in the United States, and that their efforts were invariably crowned with success. Pioneering on the technical fronts, as on the physical frontier, was nonetheless frequently colored by disappointment and occasionally by tragedy.

[50] Sketch by Magnus Bjørndal in *Norwegian-American Technical Journal,* vol. 4, no. 1, p. 13 (April, 1931).

A considerable number of the Norwegian engineers who set out for America later returned to their homeland. The most common reason for so doing is revealed in a letter by one who made the return trip. Though he belongs to a later generation than the men discussed in this chapter, his experiences were similar to those of many disappointed pioneers. He writes:

> Arrived in the United States, which meant New York for the majority, there was no difficulty in finding a job. We met comrades who had been there a year or two and who were thoroughly familiar with the ropes. In my own case a day or two after my arrival, a comrade . . . explained that his chief had recently asked if he knew of any newcomers who would like work — whereupon I went right to him and got a job. Once employed, one began to look around for something that he thought he would like better or that offered more pay. Most of us moved around quite a bit; in my case, during the five years I was in America I moved five times. . . .
>
> And now I come to that which I most want to discuss. Of us [*Trondhjem's Technical College*] classmates of 1907 about 25 per cent left for the United States, but today only one is still there. . . . I think that most of us liked America; personally I have only good memories and I think often of the many pleasant times I had and the many fine people I met. I also feel that after five years I was well acclimatized — one is quite pliable in the years between twenty-two and twenty-seven. And yet all but one of us returned home. This certainly ties up with the knowledge we acquired as to the chances and possibilities for the future we could look forward to in America. As time went on it seemed to us that we had come up a blind alley. . . . It appeared to be only subordinate work in the drafting or construction room that was open to us, and after a four to five years' stay most of us had achieved the highest salary for that work, which in the years before the World War came to $125–150 per month. Up to that point progress was quite rapid and regular, but the chances of further advancement seemed to be very small. We discovered, too, that our American colleagues in the drafting rooms were for the most part men without technical-school training, and we were even more surprised when we found that the chiefs sometimes were unable to solve a simple equation. For us who were without acquaintances or connections it seemed that in most cases further advancement was extremely difficult or at least seemed far off. . . . On the other hand we knew that these difficulties did not exist in the same degree in Norway. . . . The $125–150 per month that we earned was then worth about 300–350 crowns in Norwegian money, and even if we couldn't at once earn that much at home, we would do so in a few years or more.

The result of such thoughts was that we desired to see a little of conditions in Norway, and found that opportunities were equally good there in the years before the World War. After a few years we took a trip home, found something to do, and took root there. Of us eight from the class of 1907 who went home, two now have their own engineering firms, two are engineers at the Saltpeter Works at Notodden, and four have excellent government positions.[51]

IX

The note of pathos, without which the story is incomplete, is struck in the case of Hans Peter Herman Krag Hougen. His tragic career has been told elsewhere by the present writer,[52] but it is significant enough to merit repetition.

An official publication of his alma mater says of Hougen that he graduated in 1879 from the mechanical division of Trondhjem's Technical College; that for a short time thereafter he worked in the Cathrineholm machine shops at Fredrikshald; that, beginning in 1881, he served for several years as draftsman and engineer in the American East; and that in 1886, barely launched on a brilliant engineering career, he died at Philadelphia. That is about all. What snatches Hougen from obscurity is the chance preservation of his letters from America—letters full of courage and charm, telling a story of youth that is replete with energy, hope, and ambition. These America letters, written in the 1880's to Hougen's family in Norway, suggest anew the magnitude of the task of those who would write the history of a transplanted people.[53]

We learn, for example, that Hans accepted work in the Cathrineholm shops because he desired to gain practical experience with metals and machines. At the age of twenty, in the spring of 1881, he set out in a sailing vessel for Baltimore, there further to broaden his technical knowledge during a temporary residence in the New World. After finding a position as draftsman at Malster and Reaney's Dry Docks, he wrote to his

[51] A translation from the Norwegian of a letter written March 11, 1940, by an engineer living in Trondhjem, to the present writer.

[52] *Norwegian-American Studies and Records,* 14:227–234 (Northfield, 1944).

[53] The letters quoted here are from a selection made by J. Hougen of Oslo, Norway, and sent to the archives of the Norwegian-American Technical Society at Chicago. The letters were written in Norwegian except for an occasional English phrase.

father in Kragerø, "As soon as one can push a drafting pen and have a bit of luck with him, one is worth $8 or $10 here; theories one seldom has a chance to use; the chief draftsmen are shockingly incapable and disgustingly clever at getting by without using theory."

On the day after Christmas and on New Year's Day he worked from 7:30 in the morning until 5:30 in the evening; "but to tell the truth, I am so crazy about working that I would be at a loss without something to do. To stand at my drafting board, whistling and designing, singing and figuring, rooted in my drawings and in old memories, is so pleasant, Father." During the Christmas season of his first year in Baltimore, Hougen met a number of school friends; about twenty-five of them were in the New World.

In 1883, when Hans moved to Philadelphia to work with a cable street railway company, his letters expressed misgivings; he had disliked conditions in the Baltimore firm, but his chief interest continued to be in ships. In August he wrote:

> I did not, in changing, get into the branch that I like best—the science of shipbuilding; but I had no invitation in my favorite field, and since the new position was much more educational, broadening, and remunerative than the old (somewhat detested) job, I moved. . . . I am beginning to think that Whitton, the Scotchman who brought me here,[54] can get me into a good position (in charge of one of the cable railroad stations). That I will remain as a "road-man" is unlikely; such was never my destiny; but if I can use an easy position to learn a little about practical work and the giving of orders, I do not think I shall regret the last step.

The same letter explains the job that Hougen took with the cable railway company:

> The method of operating cable cars that I am now working on has been used for about 12 years in San Francisco and it made so good an impression at the Chicago exposition in the fall that a company in Pittsburgh, another in New York, and one in Kansas City, if not more, at once began to think of laying a similar drum-and-cable line. (The electrically-driven cars can in time ruin these railways.) . . . It was natural that Whitton and I should get into the business and we are working now for "the Cable Propulsion Co.," as it is

[54] Andrew W. Whitton.

called (with five million dollars in stock), a company that is willing to build a cable road for any who can pay and who first build 7 miles for themselves. As I have said, I hardly believe that I will be a "road-man" all my life; I think I must learn to work with my hands — and think England is the best place to learn that; I can get into a workshop there . . . with Whitton's help; but Whitton advises against going; I should work up into an independent position, he thinks, and not cross over to Europe when things are going so well.

Hougen's hunger for further education of a practical kind and his passion for ships were temporarily forgotten in his efforts to take out patent rights on an improvement of the driving machinery for the cable railway. Before leaving Baltimore he had received a letter from his friend Whitton, with whom he had worked in perfecting the mechanical improvement; the letter asked that he find out how things were with the patent for "pulling streetcars." Hans in one of his letters described the "model," which they kept in a steam laundry; it consisted of an entire cable line, with a miniature car, drawn by a steel band, that went up and down at full speed. An exhibition of the primitive model at Baltimore produced the enthusiasm and head shakings that usually accompany a new idea. There were cable-car men present, men who "belonged to the old school" and were "surprised" at the general principles involved in the mechanism after only a superficial inspection. Also present were engineers, sent from a railroad company, "who of course thought, and for a long time had thought of using a motor instead of a horse." One engineer from Boston "smiled a little" at the invention and pontifically informed the naïve ones present that "the theory was sound but the practical execution almost impossible." Another said, "A brilliant idea for an elevated railroad but hardly suited for the streets."

Hougen told of a visit to the patent office in Washington, where he saw a great number of "good and crazy ideas." He added, "You may well wonder why, in spite of such examples, I am in the patent game. . . . My idea was found to be good . . . and now a proper model has been worked out. . . . My

superior, Rice, says that my idea is used in velocipedes." The idea for the invention, as a matter of fact, had come from an axle joint used in Germany and described in one of Hans's schoolbooks, and from a wheel mechanism used in the spinning machine. He had put the two principles together and applied them to the problem of pulling streetcars; an old mechanism was thus applied to a new use. The drawings and descriptions in his letters of the patented mechanism are as exact as a scientific treatise.

Later in the same year, 1883, Hougen wrote explaining why he had not left for the British Isles:

What, despite everything, has kept Whitton and me for a year in the cable-road business is, first of all, the joy of seeing our large railway system develop to everyone's pleasure (so we can call ourselves cable railroad engineers); and, secondly, the fact that we will have our *patent* tested by the firm; and if it works and we get the patent from the great men in Washington, we will be sitting pretty. To overcome "slip" is a very great problem in cable propulsion. Much is written about this from San Francisco to New York, in fact all over America, but no means has yet been found to prevent it except ours. Will ours do it? Several engineers think so; they think it so definitely that our invention has been recommended for use in Union Line's (our company's) new road. Designs for the models are all ready; the preparation and casting of all the wheels that belong to the mechanism will cost $1,200 if not more. But the mechanism will be used — a patent in Whitton's name has been applied for.

Then followed detailed explanations of the invention. An answer from Washington was expected in February of the next year. "How exciting the first trial will be!"

In his next letter, Hans excitedly and somewhat incoherently told of having received word from his chief, George Rice, who at the time was out on the west coast:

He has mentioned our discovery to one of the biggest inventors out there (San Francisco) and he, Mr. Lawe, has said that we have solved the riddle that he has racked his brain for a long time trying to solve — that is to say, I have solved it — hm — I like to say I have solved it, for that will never be known either in writing or in daily life; but it is recognized, in fact all recognize, that I am the one who proposed the idea; *but no one says it.* Am I not vain? . . . All right, Lawe also says that it is the best idea he could think of

and that it will certainly have a strong influence on hoisting machinery in general (in mines, *etc.*).

Finally the long-awaited letter arrived from Washington; the patent was granted.[55] Rice got Whitton, in whose name the patent was taken out, to surrender one third of his rights to Hougen and another third to himself. The three then entered into a partnership to exploit the new mechanism. Rice, who had already put up $350 in cash, agreed to have a new model made and to take out patents in England, Belgium, and France. Hougen spoke glowingly of Rice, a civil engineer about fifty years old, and a member of one of the best families there. He continued:

His father, who built Memorial Hall for the Philadelphia Exposition and was chief engineer for the Reading Steam R. R., was once so prosperous that he drove a carriage with four horses. Rice himself has traveled about the world. He has not yet spoken to the president about the patent. . . . It is not only for cable roads that our patent can be used — for all hoisting contrivances in mines it has great value; and it is especially there that Rice thinks the patent has a future. A mining engineer who was recently in the office was quite enthusiastic at seeing so much done with so simple a mechanism. The chief thing is — there is no more expense with our methods than with the simplest lifting arrangement in use up to now.

Hougen was confident that Rice and one of Philadelphia's best attorneys could prevent others from taking away the patent rights — a possibility that had given him many sleepless nights — and his thoughts turned once more to working with ships — this time in Scotland. "If everything goes well," he wrote in January, 1884, "then I will be at the workshop in Scotland next summer and let the cable road take care of itself." But before he could leave, changes took place within the Philadelphia Traction Company which made it inconvenient for him to carry out his plans. Writing in September, he explained: "Mr. Rice, 'the chief,' has left us. He does not see eye to eye with the president; we were all ready to go when Whitton was

[55] Number 295,701 (March 25, 1884); device for transmitting power. "This invention relates to certain improvements in the class of apparatus which has been proposed from time to time for driving machinery for cable railways, and its object is to prevent slip and consequent wear and tear of the pulleys and wire rope or cable."

chosen as Rice's successor, and Rice urged him strongly to stay until the railroad was completed."

So the two friends remained at their posts but were ready to leave when the street railway project was finally liquidated. Whitton was to go where Rice went, probably to Washington or Baltimore to do similar work, if the Philadelphia railway was a success. Hougen mentioned having seen a number of his Norwegian friends: Holth, who liked the patent very much; Heidenreich, who had been recently married; and two other Trondhjem men, both of whom were soon to be married in Chicago.

Whitton and Hougen finally sold their shares in the patent to a man named Whetherill. Hans, after a trip home to Norway in the summer of 1885, at last set out for Glasgow, where he became established with J. and G. Thomson in "a worker's position." The work was heavy and he once wrote that he was "tired from tip to toe, and yet as healthy as I can ever be while working." While in Scotland he also met several of his friends from the technical college.

Hans had thought of remaining at Glasgow, learning the art of shipbuilding from the bottom up, but suddenly he had word from Whitton in Philadelphia, with a tempting offer for employment which he felt he could not reject. So in the spring of 1886 Hougen returned to Philadelphia. The reception given him by his friends is described in a March letter: "Whitton welcomed me as if I were his brother. . . . All (workers and engineers) have received me in the warmest manner; yes, here everything has been cheerful since my return. The railway works brilliantly; all are satisfied with it, and the president not least. . . . I surprised all the Norwegians here; all were glad to see me. . . . All is warmth and sunshine."

Cheerful, happy, full of plans during the spring of 1886, intensely interested in his work and looking forward to another visit to Norway in the near future, Hougen suddenly contracted typhus and died on Easter Eve, at the age of twenty-five.

Though Hougen's story is unusual in several respects, it is nevertheless true that a sizable group of the engineers failed to realize their ambitions in the land of opportunity. A quick glance at the records as published in the anniversary volumes of the technical schools reveals that some apparently vanished completely, even their families in Norway having no knowledge of their whereabouts. Others remained in subordinate technical positions, and a small number took to farming, shopkeeping, and similar activities which, though respectable enough, were not the goals sought by the eager graduates when they sailed for America.

Wigtel, interviewed shortly before his retirement, expressed the opinion that Norway was making a mistake in educating so many engineers when it was a certainty that a large number thus trained at direct or indirect state expense would leave at the first opportunity for the New World. But he was quick to add that he himself had employed many of his countrymen and always found them excellent engineers.[56] His experience, multiplied many times over, was to be the experience of American technology generally, not only with the pioneers, but also with those who followed in their tracks.

[56] *Nordisk tidende,* April 29, 1926.

A PHILADELPHIA STORY

THERE are two Philadelphias. The first is the "green countrie towne" of William Penn, a paradise of Quaker and German tranquillity. This Philadelphia is known for its historic buildings, such as Independence Hall and Old Swedes Church, and for its old, exclusive families. It is the home, too, of Benjamin Franklin and David Rittenhouse; a center of learning and discovery, where the Franklin Institute, proud of its priceless heritage, gives aid to science and the mechanic arts.[1] It is a city of select clubs and lovely parks, broad boulevards and charming suburbs.

But there is another Philadelphia. This is the city of the immigrant, where the Scotch and Irish held the balance of power in the years following the Revolution; where Russians and Italians added their strains to those of the Swedes, Dutch, French Huguenots, and Germans. Fifty-five per cent of the population claim foreign parentage, and the slum edges boldly up to Congress Hall. This Philadelphia ranks below only New York and Chicago in population and industrial output. Most important are its textile plants, established in the eighteenth century; but the Baldwin Locomotive Works and the E. G. Budd Manufacturing Company provide engines and streamlined trains for America's railroads, and the J. G. Brill Company produces half of the country's streetcars. Philadelphia, a center of giant oil refineries, Stetson hats, storage batteries, and Philco radios, is also the city of the Hog Island shipyards and of William Cramp and Sons. It is headquarters of the Pennsyl-

[1] For fuller information see Sydney L. Wright, *The Story of the Franklin Institute* (Philadelphia, 1938).

vania Railroad Company, and as a great shipping center it maintains commercial contacts with all parts of the world. It is this Philadelphia that claimed William Sellers—the president of William Sellers and Company, the Edge Moor Iron Company, and the Midvale Steel Company—an inventor of machine tools and of our standard system of screw threads. It is this Philadelphia that produced Frederick Taylor, high-speed steel, and scientific management. And this Philadelphia drew young engineers from the technical schools of Norway.

Three of these engineers made such conspicuous and original contributions to the technological development of the country and to industrial life generally that they attracted the attention of the Franklin Institute and other scientific bodies. Their work was thoroughly investigated, and they lived to see their inventions become standard products here and abroad. They were Tinius Olsen, Henrik V. von Zernikow Loss, and Mauritz C. Indahl, all graduates of Horten's Technical School and all of them mechanical engineers. Olsen had the distinction of producing the first commercial testing machine. Loss succeeded in manufacturing an all-steel wheel, and put this wheel on the all-steel railway car that had just been produced. Indahl, a modern Gutenberg, made the monotype machine what it is today, a contribution of lasting value in the cultural as well as the technical field.

II

As late as 1884, the author of an article on engineering wrote:

> To conquer time and space by joining the two oceans with the railway and the telegraph; to drive a five thousand ton ship across the Atlantic in the face of adverse gales; to erect the structures that now span the Mississippi, the Niagara and the East River; and to dot the continent with buildings, such as may be seen in the streets of any of our cities; would seem to require the most intimate conceivable knowledge of all the properties of all the materials used in construction. Yet such is far from being the case. Indeed the art of construction, perhaps more than all others, is involved in mystery and obscurity. . . . The knowledge of materials is at present, at least, an absolutely empirical one. . . . Any predictions from existing data regarding a new material, or the effects of a new process

on an old one, are hazardous in the extreme, and should be received with the greatest caution. "Experimenta docet" seems to be the only motto for this science. Before the constructor makes use of either a new material, or an old one in a new form, the only safe method is to experiment.[2]

Despite the prevalence of such unscientific and haphazard methods, the testing machine was not entirely unknown in 1884. Testing of a sort had long been practiced on anchor chains in England and elsewhere. In 1852 "a good laboratory machine was made for testing in compression as well as in tension." In that year Ludwig Werder of Nuremburg made "a horizontal machine in which the hydraulic press for straining was at the same end of the gauntry as the lever for measuring the stress."[3] In America a Major Wade designed and built for the federal government a machine that made tests of cast iron for ordinary service. This machine, produced in 1855–56, was later remodeled and improved by a Captain Rodman and was used at the Washington navy yard and in the Army Building, New York City. Others experimented, among them John A. Roebling in New Jersey and George W. Plympton. The latter succeeded in producing a machine for testing rods used in bridge construction.

The Civil War diverted attention from these investigations, but after the war's end it was announced that Fairbanks, Morse, and Company had built the first platform testing machine, for Colt's Armory. The same firm also designed a similar machine for Columbia College. The American Society of Civil Engineers on June 5, 1872, resolved to urge upon the federal government the importance of a complete series of tests of iron and steel, and of the need for formulas deduced from such experiments. Congress passed a law providing for the appointment of a board to test these metals, with an appropriation of $75,000. The board awarded the contract for a testing machine to A. H.

[2] Arthur V. Abbott, "Testing Machines, Their History, Construction and Use," in *Van Nostrand's Engineering Magazine,* 30:204 (March, 1884).

[3] J. H. Wicksteed, "Notes on the History of Testing Machines with Special Reference to European Practice," in American Society for Testing Materials, *Proceedings,* 8:622 (1908).

Emery of Chicopee, Massachusetts, who in 1879 completed one with a capacity of 1,000,000 pounds. This machine, first used at the Watertown Arsenal, could test a column 30 feet long and 2½ feet in cross sections.[4]

These and several other machines—chief among them one developed by a Professor Thurston for making experiments in torsion and graphic recordings, and another by Arthur V. Abbott which recorded the results of tests made in other than torsion stresses—were indications both of the general acceptance of the need for testing building materials and of an understanding of the general principles involved. Samples of materials were broken in the machines, which then registered the amount of stress required and the strain produced. Despite this progress, however, no one had succeeded in producing a commercial testing machine before Tinius Olsen put his models on the market. To him goes the honor of making the testing machine an essential part of American industry.[5]

III

Tinius Olsen was born in 1845 in Kongsberg.[6] His father was employed in the local gun factory, making rifle stocks of birch or walnut. He worked at home, where young Tinius assisted by cleaning the brass mountings on guns being repaired or altered. At the age of thirteen Tinius entered a private drawing school, where his technical interests were sharpened. There he conceived the idea of going ultimately to America. After confirmation in the church he prepared to be a stockmaker and began

[4] *Van Nostrand's Engineering Magazine,* 30:204–214, 325–344, 382–397 (March–May, 1884).

[5] See articles by his son, Thorsten Y. Olsen: "Recent Developments in Testing Machines," in *Forging and Heat Treating,* 7:66–69, 131–134, 162–165 (January–March, 1921); and "Testing Machines as Related to the Foundry," in *American Machinist,* 53:525–530 (September 16, 1920).

[6] The following account of Tinius Olsen is based in part upon articles in *Norwegian-American Technical Journal,* vol. 1, no. 2, p. 2 (May, 1928), and vol. 6, no. 1, p. 10 (April, 1933); *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 100; Wong, *Norske utvandrere,* 149; Chicago Norwegian Technical Society, *Year Book, 1925,* 11; Sv. Herbert Herbransen, *Ingeniør Tinius Olsen, en norsk banebryter for materialprøvemaskiner i Amerika* (Oslo, 1925); *Nordisk tidende,* December 9, 1943; and an interview with Thorsten Y. Olsen in Philadelphia, May 15, 1941.

an apprenticeship under his father. During this training period, Tinius, with a comrade, began his study of English, tutored by a turner who had lived in America.

Having completed his training as stockmaker, Tinius mastered the art of the locksmith. When denied the privilege of working as a locksmith, he quit his job at the gun factory and set out for Horten to find work in the navy's machine shops. Despite lack of money, the death of his father, and many hardships, he went through the brief training period at the technical school and emerged, in 1866, at the head of his class. Then he again obtained work in the navy shops.

As a result of Olsen's skill in the use of machinery, he was made foreman of the machine department of the well-known Trondhjem machine shops. While at Horten, Tinius had privately instructed backward students in mathematics and mechanics and had occupied himself with machine designing and other technical problems. He discovered at Trondhjem, however, that he had much to learn. The shops, which turned out almost every article made of iron and brass, from ships and locomotives to flatirons, demanded great versatility. Olsen applied himself to his work with characteristic energy and thoroughness. He did not, however, relish the new job, which called for instructing men older than he who were resentful of his teaching. He applied for a government stipend to broaden his experience in a foreign land, received a modest grant, and resigned his foreman's position after a year and a half. He then went to Newcastle, England, where he found it impossible to obtain employment in machine designing. At that time his former superintendent at the Horten shops, Christian Steenstrup, was in Newcastle. Steenstrup was unable to find work for Olsen in England, but through English connections, he heard of William Sellers and Company in Philadelphia. He recommended that the young man try his luck in the New World and gave him a letter of introduction to Sellers. Tinius made a last effort to get a job as a designer in Liverpool but, failing, took the first ship to New York. He arrived in Philadelphia in August of 1869.

It is not difficult to visualize the twenty-three-year-old Olsen during his early days in Philadelphia. In many respects his story follows a familiar pattern. He suffered from the oppressive heat, but he did find work as a designer with William Sellers. He craved acquaintances and an opportunity to speak English. He took to visiting Lutheran churches, notably one located at Broad and Arch streets, and he eventually became a regular member of a Sunday Bible class in the church. What he sought most was instruction in English, but the Sunday-school experience was to have far-reaching effects in his professional life as well.

In the Sunday school were two young teachers, the brothers Riehlé, who had recently bought a little workshop for the production of commercial scales. They soon discovered that their new student was one of Sellers' designers. When the Riehlé brothers received a request for a machine to test the strength of boiler plate, they asked young Olsen whether he could make drawings of such a machine. Tinius answered that he would make the drawings if they would furnish details as to what was needed. Evenings were then devoted to the designing of the first machine, one with a capacity of 40,000 pounds, to test boiler plate. Thus began for Olsen a long career devoted almost exclusively to the design and production of commercial testing machines.

Later an order came for a much larger machine which, like the first, had to be constructed in a shop intended for the production of scales. Parts of this machine were larger than any the workers in the shop were used to handling, and Tinius' presence was needed so frequently that he was invited to take over the direction of the plant. On January 1, 1872, Olsen became director of the Riehlé Brothers plant, although he regretted leaving Sellers, where he still had much to learn. He held this position for eight years and helped to establish the firm securely in the industrial life of Philadelphia. He planned and built new shops and threw himself into the construction of scales as well as of new testing machines. Several of the lat-

ter were exhibited at the Philadelphia Exposition of 1876. Needless to say, many of his discoveries were patented in the name of his employers. Olsen apparently asked to be taken in as a partner. He was married and sought a more remunerative and secure position than that of manager. His suggestion was received with little enthusiasm, and late in 1879 he was informed that his services would terminate at the end of the year.

Despite the sour note marking the end of Olsen's relationship with Riehlé, his work with this firm was deeply significant. The direction of all his subsequent efforts was determined by the pioneer contributions that he made with the Riehlés during the 1870's. His work, in fact, had been closely observed. The Franklin Institute, alert to advances on the technological front, quickly realized the significance of the young engineer's efforts, both to industry and to Philadelphia. Its committee on science and the arts in 1879 entrusted a subcommittee with the examination of Olsen's testing machines and their appliances. The committee's final report reads in part:

> These machines are of various designs, adapted to different materials and purposes, with capacities ranging from 1000 lbs. to 300,000 lbs. In most of them the article to be tested is placed so that one end receives the stress from the source of power, while the other end is acted upon by a system of levers terminating in a graduated beam, so that this stress can be accurately counterbalanced and weighed. But in some of the machines one end of the article is held in a fixed abutment, while the power, which is applied at the other end, has its abutment on the weighing mechanism. In other words, the first-mentioned machines have the article placed between the power and the scales, whilst in the last the power is placed between the article and the scales. The stress is produced in various ways in the different machines, according to their capacities. In the small ones, for testing threads, fabrics, cement, wire, etc., a simple screw is used, the nut being revolved by a handwheel or lever. As the machines increase in capacity, so the power to produce the stress is increased, as follows: hand-power through bevel gearing to nut on screw, hand-power through worm and worm-wheel to nut on screw, belt-power through bevel gearing or worm and worm-wheel to nut on screw, hydraulic jack with single pump worked by hand, hydraulic jack with single pump worked by power, and, finally, in the large machines, hydraulic jack with triple pump worked by power.

In all these machines the weighing apparatus consists of a well-arranged system of simple levers supported on ample knife-edges, the whole being convenient to operate, properly proportioned and handsomely designed, and accurate withal.

Referring to specific machines designed by Olsen for the Riehlé Brothers, the report says of a 40,000-pound vertical machine that the "general design . . . is good. It is compact, while, at the same time, the parts are accessible . . . . One man can make careful tests, as everything is within easy reach." Another much larger, vertical machine for testing materials in the actual shapes and sizes used in construction was examined; this had a capacity of 100,000 pounds and was built for the Pennsylvania Railroad Company's shops at Altoona. "The arrangement of the platform, levers and jack is remarkably compact, and this . . . enables tests to be made of articles of unusual length." One man could "conveniently control the pressure and move the poises without changing position. The location of the specimen is, however, inconveniently high." A third vertical machine, still unbuilt, was thought to have advantages and promised "to be superior in many respects to the other forms." A horizontal machine with a capacity of 300,000 pounds, designed to test chains, was in daily use in a Philadelphia firm. In this machine the stress was produced with a jack worked by a triple pump driven by belt power. While results were generally favorable, the committee criticized the machine on some points. Tools for holding ends of specimens while being tested for tensile strength[7] were said to be improvements. The report concludes:

The various forms and sizes of testing machines designed by Mr. Olsen and manufactured by Messrs. Riehlé Bros. really constitute a new industry in this country, and particularly in this city. Messrs. Riehlé Bros. have undoubtedly increased the interest in, and desire for, more extended data as to the qualities of materials. They have placed within the reach of manufacturers good, practical and reliable means of ascertaining these qualities, and it is to be hoped that their efforts will tend to aid the continual improvement of our products, and thus be of great service in the advancement of our mechanical industries.

[7] Patent numbers 213,525 and 213,586 (March 25, 1879).

Although we may criticize some of the details of their machines . . . yet we heartily commend their aims, and think they deserve great credit for what they have already done and are now doing.[8]

IV

When Olsen, in 1880, found himself without a job he was not without a partner and companion. It had been his good fortune to meet a young Swedish woman, Charlotta Yhlen, who was studying medicine at the Philadelphia Women's Medical College; in 1874 they were married. His wife's bold intelligence and general understanding proved factors of no small importance in Olsen's career. Asked once to what he attributed his success, Olsen answered quickly, "My interest in mathematics and my wife."

Olsen was not slow to determine upon a course of action. Ten years' experience with testing machines had shaped his interests and given him a profession; any new direction was unthinkable. His head full of plans for better machines, he began at once to make drawings in his home. Work on a new machine was completed, patent applications made in January, 1880, and on June 1 of the same year the patent was granted.[9] This machine was of "fundamental importance in its technical field for *it became the basis of all testing machines later produced in America.*"[10] He constructed it at Fairbanks, Morse, and Company, because he thought this well-known scale firm would become interested in the project and take over production. Nothing came of this scheme, however, since Olsen was unwilling to serve Fairbanks as a general employee. The difficulty in finding a company to produce his machine proved to be a significant stimulus: prompted by his wife, he decided to go into business for himself. Their combined capital was very small: at best they could produce only a few thousand dollars. But, his mind made up, Olsen established a little workshop at 500 North Twelfth Street, a fortunate location near two main

[8] "Report of the Committee on Science and the Arts on Olsen's Testing Machine, Riehlé Bros., Manufacturers," in Franklin Institute, *Journal,* 108:36–40 (July, 1879).
[9] Number 228,214 (June 1, 1880).
[10] Herbransen, *Ingeniør Tinius Olsen,* 22. Italics are Herbransen's.

avenues in Philadelphia. This plant eventually grew to be the largest of its kind in the world, but only after serious competition had been overcome. His former employers enjoyed reputable ratings and could draw on large reserves of capital. Olsen had only a superior machine to offer, but in the end this proved enough.

His methods were simple and effective. He sent out printed circulars, with illustrations of his machines, to various factories. Schoenberger and Company of Pittsburgh ordered a machine on the condition that they would pay for it only if satisfied with its performance after two months' use. The machine was quickly made and delivered. Despite the competition of Olsen's former employers, his machine met the test and was paid for. Olsen was later informed that his competitors had put on a heavy campaign to place one of their machines with Schoenberger, but they were finally forced to take it back.

In 1881 Olsen exhibited his testing machine at expositions in Cincinnati and Atlanta. Since it was his policy never to borrow money and since his wife was determined to have the machine exhibited, she pawned her diamond ring to raise the necessary funds—a wise investment, for the machine won gold medals at both expositions. In 1882 the Olsen company took an order for the first 200,000-pound universal testing machine to be made; it received good publicity and generous business support. The next year Olsen built his first machine with 100,000-pound capacity, and one to test the tensile strength of feathers! Both of these were exhibited at an exposition in Chicago. In 1883, too, he produced his first 10,000-pound machine for steel and other wire, and in 1891 the first autographic universal machine with 300,000 pounds' capacity. In 1908 he received orders to build a 10,000,000-pound capacity machine to test compression for the federal government. It was built at Pittsburgh, where it was first tested in the presence of members of the International Association for Testing Materials, which met in the United States in 1912.[11] Now in use at the bureau of standards

[11] Olsen exhibited his machines in Cincinnati and Atlanta in 1881, Chicago in 1883, New Orleans in 1885, Chicago in 1893, Philadelphia in 1889, Paris in 1900, St. Louis

in Pittsburgh, this is the largest testing machine in the world. Of all Olsen's products, the universal testing machine has been most widely used. His machines are found in every country and are used in the laboratories of leading universities and technical schools, factories, and all testing agencies, private and governmental.

V

Tinius Olsen is so unmistakably identified with the development in America of the commercial testing machine that it is desirable to investigate more fully his monumental work with this mechanism. The Olsen Testing Machine Company today advertises hundreds of machines; obviously it is impossible to give here anything like a complete account of the founder's technical contributions.

The Franklin Institute was first to make a careful study of Olsen's new machines and to publish the results. The report made by the institute's secretary on November 15, 1882, is significant. Analyzing the universal testing machine of 50,000-pound capacity, this report speaks of it as "combining certain novel and useful features, introduced for the purpose of subjecting materials used in construction to every variety of strain." Designed for the Rensselaer Polytechnic Institute of Troy, New York, it was capable of making tensile, crushing, transverse, and torsional tests. Strain was applied through the device of screws and gearing, and the machine was operated by a crank. "The strain to which the specimen of material operated upon is subjected will bear upon the platform of the machine, which is supported on a system of scale levers, and the amount of the strain balanced and indicated on the beam, in the main similar to the arrangement of a platform scale." The mechanism was "provided with an arrangement for applying intermittent strains, whereby a specimen under a certain strain may be instantly subjected to a certain increased strain and again as suddenly released. . . . With this machine, then, the experimenter is enabled to apply a very gradual and quietly increas-

in 1904, Jamestown in 1907, Alaska in 1909, and San Francisco in 1915. In the last exposition he won three grand prizes.

ing strain, which can be obtained by the use of screws and the crank motion; also, when desired, a sudden and intermittent loading or series of strains of any desired duration." Machines of this type had been built up to 200,000 pounds' capacity.

The same report also mentions a horizontal chain-testing machine, built for the Iron City Chain Works of Pittsburgh, which was capable of stretching out and testing 15-fathom lengths of chain. It consisted of a straining device and a recording device, both arranged at the same end of the machine.

The straining device in this case consists of hydraulic cylinder, power pumps and a device for changing and stopping the motion of the piston in the cylinder without stopping the pumps as well as an automatic stopping arrangement at each end of the stroke of the piston. . . . The hydraulic cylinder presses against the main levers, and this again transfers the strain to the equal beam, which alters the horizontal stress to a vertical one, and is further transmitted through the intermittent lever to the beam where it is balanced and recorded.[12]

The Franklin Institute, in the early 1890's, was sufficiently impressed by Olsen's machines to award the designer its highly prized Elliott Cresson medal. The award was accompanied by another report on his work, which called attention to his new autographic machine:

The Olsen testing machine is the result of continued efforts of the inventor to improve his original machine and to meet the additional requirements demanded by progress in the arts of metallurgy and construction in metal. The earlier investigators in these arts were careful to ascertain the ultimate strength of materials; afterwards a knowledge of the properties of elasticity and ductility were deemed important and were crudely examined into by bending specimens under the hammer. As the art of making structural work progressed, these properties became of importance in estimating the strength and durability procurable by selections of materials and questions of cost were affected by such selections. Exact ascertainment and expressions of all the properties, ultimate strength, limits of elasticity, both in dimensions and in force, and limits of ductility, expressed in force and dimension, were all demanded for intelligently applying materials to use, as well as for comparing the values of different materials.

[12] "Olsen's Testing Machines," in Franklin Institute, *Journal,* 115:39–43 (January, 1883).

The mode of testing these properties or functions of materials under strain, by weighing, and ocularly observing the weight and measuring from time to time by hand the variations in distance of marks previously made upon the specimen, as they changed under the stress applied, was found to be too slow and uncertain, and, therefore, very unsatisfactory, first, because there were so many tests required and the making of them was too long and tedious, and second, the changes which took place during tests occurred in such rapid succession as often to defy accurate observation.

Mr. Olsen's machine is designed to meet these requirements and furnish easy means of prompt application of the specimens to the machine, and of adjustment of the machine to the specimens, with the least requirements in preparation.

Discussing in detail the machine's system of mechanisms, the report states:

The combined effect of the several mechanisms is to enable the operator, with rapidity and certainty, to submit specimens to the action of the machine under conditions favorable for comparison of results, and to secure a graphic record of all the phenomena of change of form and variation in stress which occur at every stage of the test, to suit different dimensions of specimens and different rates of application of force to any required extent, and when desired, to closely feel the effect of the stress upon the specimen through the frictional gear with a delicacy of working, facility of observation and accuracy of record never before attempted.

The Franklin Institute's committee on science and the arts recognized that:

The increased complexity of this machine over others requires a more careful handling. . . . Their opinion is that this testing method is a long step forward toward making such machines thorough instruments of precision, and it introduces instead of the numerical, the graphic record. . . .

In view of the great ingenuity displayed by the inventor in arranging the several parts of the machine, notably in the mechanism which produces a graphic record of the test, similar to the indicator of a steam engine, and thus brings to perception at a single glance the variation in the strain of a number of specimens as well as the work required to break such specimens, the award of the Elliott Cresson medal is recommended.[18]

Commended by Philadelphia's Franklin Institute, Olsen

[18] "The Olsen Testing Machine," in Franklin Institute, *Journal,* 131:81–88 (February, 1891).

found that his reputation grew with the excellence of his products. New machines were produced to meet new demands and to improve upon the performance of old ones. The technical journals noted some of the more significant innovations down through the years. Most of the articles or reprinted speeches after 1907 were prepared by Thorsten Y. Olsen, the inventor's son, who is now president of the Olsen Testing Machine Company. In 1908, for example, he mentioned a new 600,000-pound universal testing machine; one of these had been installed in the testing laboratories of the United States Geological Survey at St. Louis; another had been recently put into use in the civil engineering department at the University of Pennsylvania. It was produced in response to changed methods of construction —the use of reinforced concrete, large beams and columns. In the early years of the twentieth century a demand had developed for the testing of full-sized structural members.[14] At about the same time Thorsten also described two recent designs for tensile-testing machines using the pendulum principle of weighing. The first was designed to meet specifications, not covered by existing machines, for testing materials, from light yarn or thin paper to heavier textile materials; the second was to meet the demand for an automatic quick-acting machine of moderate capacity and low cost, and was intended primarily for wire tests.[15]

Announcement was made the next year of a machine for "cold bend" testing of iron and steel specimens. "Instead of the time taken by the bending tools in a regular testing machine, this requires only three minutes to bend a specimen double, that is, 180 degrees around a pin, which is of great advantage to a steel mill or other establishment, where many tests must be made in a short time."[16]

During the years 1908–14 a steady stream of new and in-

[14] "Special Features of a Recently Installed 600,000-Lb. Universal Testing Machine," in American Society for Testing Materials, *Proceedings,* 8:626–635 (1908).

[15] "New Forms of Pendulum Testing Machines," in American Society for Testing Materials, *Proceedings,* 8:636–639.

[16] "A New Testing Machine," in *American Machinist,* vol. 32, part 1, p. 35 (January 7, 1909).

genious mechanisms made by Tinius Olsen reached the market. During 1908 a machine was developed that marked a forward step in the construction of large testing machines. Its main feature was a new system of transmitting to the scale beam the pressure developed in the hydraulic cylinder. The standard commercial lever testing machine had weighed the entire pressure directly on three main levers, from which it was then transmitted to the scale beam. The high cost of the old type of machine had limited research work and deprived the engineer of data he now needed. Designed for the new testing laboratory in the Rensselaer Polytechnic Institute at Troy, New York, the new machine claimed an "accuracy exceeding one-third of one per cent." A 10,000,000-pound compression testing machine of the same general design was under construction at the time of the announcement; it was to be delivered to the United States Geological Survey. Thorsten Olsen says of it: "With the knowledge of what the smaller machine will do, the success of the larger one is assured, and it is safe to predict that it will exceed all expectations as to accuracy. . . . The testing of full-size structural members is assured. Testing machines far more accurate and reliable than required either in practice or in research work can be obtained at a reasonable cost by this type of construction." [17]

Prior to 1909 the hardness test for iron, steel, and other metals had been used primarily in research work in the development of high-grade tool steel.[18] Thanks to another Olsen machine, this test became more versatile:

> [It] stepped beyond the field covered by the research laboratory and is demanded for determining the proper material, from the standpoint of machining and finishing, for maintaining a constant and uniform hardness in gearing, such as used in automobiles; for determining the uniformity of wheel tires, so that two tires of the same

[17] Thorsten Y. Olsen, "Principal Features of a 1,200,000-Lb. Testing Machine with Special Reference to a New System of Transmitting the Pressure Developed in the Hydraulic Cylinder to the Scale Beam," in American Society for Testing Materials, *Proceedings,* 9:663 (1909).

[18] J. A. Brinnel in 1900 invented the method of hardness testing which bears his name: measuring the depth of impression made on a specimen by a hardened steel ball under a given pressure.

hardness may be selected and placed on the same axle to produce uniform wear; and a number of other practical applications of this nature can readily be cited. . . . The difficulty has been to construct a practical form of machine admitting of use in every-day shop practice.

The machine here described was designed for the Baldwin Locomotive Works for testing tires and other materials used in the construction of locomotives. The specimen is placed between a steel ball and the frame of the machine. The load is applied by weights at the end of one lever, "which causes the steel ball at the end of the other lever to penetrate the specimen. The penetration is measured automatically to ten-thousandths of an inch by the instrument . . . on the top of the main lever." The machine, adapted to a large range of specimens, could measure over 500 degrees of hardness for each variation of load.[19]

Early in the 1900's rubber had been subjected to tests by the United States government and possibly by a few extensive users, such as railroads. But by 1910 testing was "passing beyond this stage and the rubber manufacturers are devising more thorough tests to determine the quality of their product." At the meeting of the International Association for Testing Materials in 1909, "the question of rubber testing and machines for that purpose was considered, showing a universal tendency toward more complete methods for testing this material." The result was a machine produced by Olsen at the request of the chief chemist of the B. F. Goodrich Rubber Company, "in order to obtain more complete data and to determine various characteristics of rubber not obtainable on any present testing machine." Intended at first to be used only for autographic tensile tests, the machine was actually designed as a universal autographic rubber-testing machine capable of performing a number of different tests.[20]

One of the best binders used in road construction is pitch,

[19] Thorsten Y. Olsen, "A Machine of New Design for Hardness Tests," in American Society for Testing Materials, *Proceedings,* 9:664–666 (1909).

[20] Thorsten Y. Olsen, "An Autographic Rubber-testing Machine," in American Society for Testing Materials, *Proceedings,* 10:588–591 (1910).

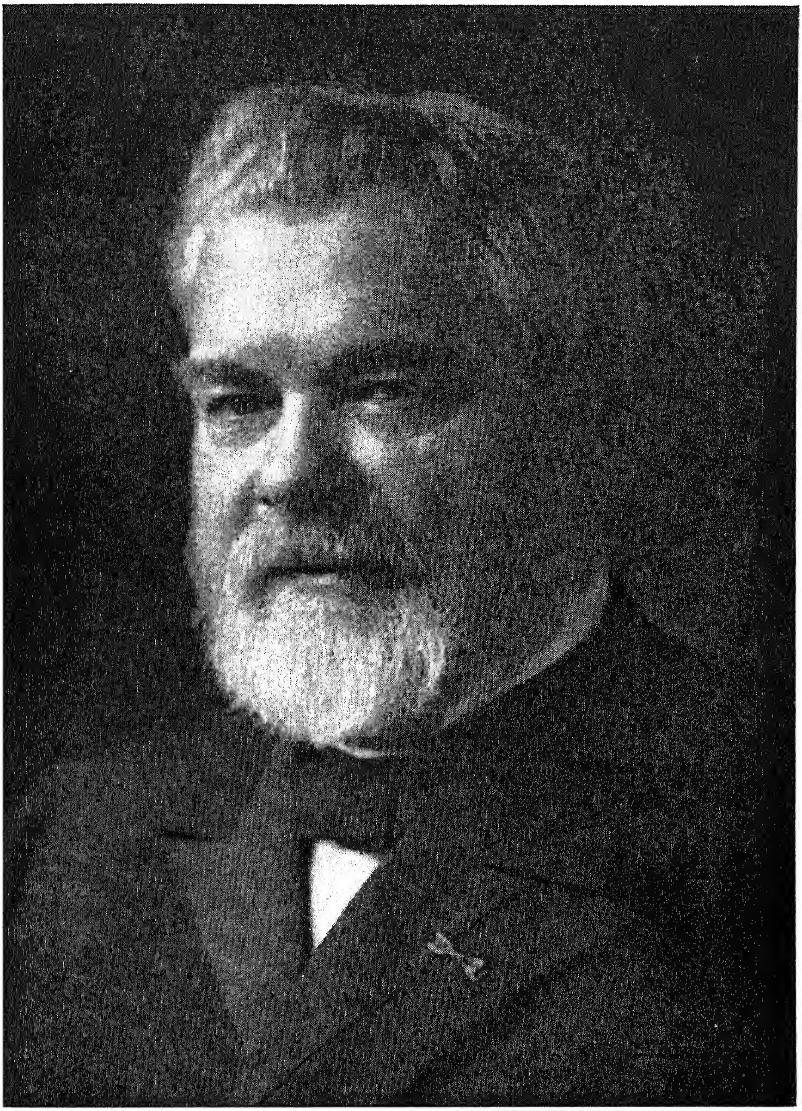
the value of which derives largely from its adhesive quality. A new method of testing the adhesive strength of pitch was devised by the United Gas Improvement Company, who then turned to Olsen for a machine embodying their principles. The result was "a new type of impact tension-testing machine which will subject all samples of pitch to the same conditions, and will provide a test which can be duplicated at any time on any machine built on the same principle." The method of testing consisted of "determining the amount of energy required to force apart two specially designed dies held together by pitch." A machine of this type, it was pointed out in 1910, could be arranged to make impact tension tests of standard cement briquettes. A machine "of larger capacity built on this principle, with the proper gripping device, would form an ideal machine for impact tension tests of metals or for testing small nicked bars over a die in determining the fragility of steel." [21]

The impact test of steel had been little used on a commercial scale, although it was recognized as one of the most important tests and one essential for determining the highest quality of a steel. The reason was that no standards or specimens had been formulated and engineers had used their own varying methods. "The advent of the automobile . . . and the consequent development of special and heat-treated steel, has greatly advanced the science of steel testing, and where a couple of tests would formerly have sufficed, we now have a large variety, with the tendency at present toward the most severe test, that of impact." Olsen developed a machine that would break a steel specimen over an anvil. The impact was confined to a very small surface, and "by using a pendulum to apply the impact, the work required to break a specimen can readily be accurately recorded." [22]

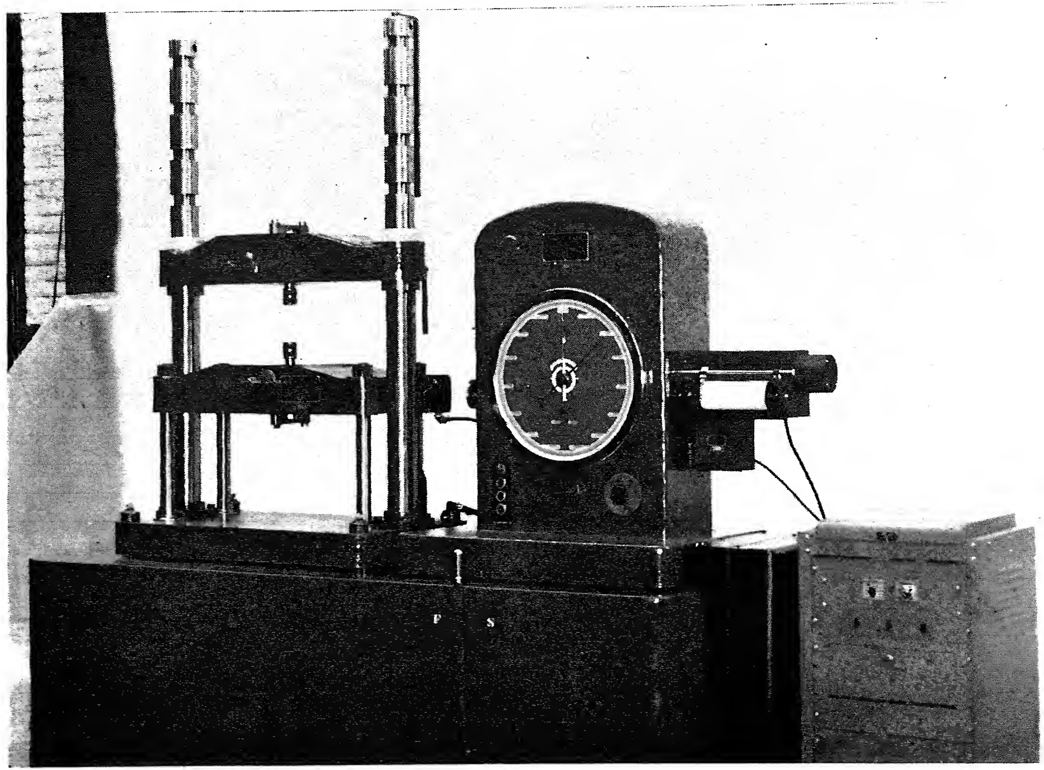
The transverse test was most often used "in general foundry practice to determine the physical characteristics of cast iron."

[21] Thorsten Y. Olsen, "A New Machine for Testing Pitch," in American Society for Testing Materials, *Proceedings,* 10:592–594 (1910).

[22] T. Y. Olsen, "New Types of Impact Testing Machines for Determining Fragility of Metals," in American Society for Testing Materials, *Proceedings,* 11:815–818 (1911).



Tinius Olsen



A Modern Testing Machine Produced by the Olsen Testing Machine Company

The tension test, also widely used, required a heavy and expensive machine; because of the brittleness of cast iron, its specimen had to be specially prepared and care had to be taken in gripping it in the machine. The transverse specimen, on the other hand, required no machining, and the machine devised by Olsen for making the test was small, compact, and inexpensive — well within the reach of any foundry "interested in the quality of its daily output." The demand had been for a machine that would "automatically record the stress-strain diagram to such a scale that the deflection for any given load may be read to a thousandth of an inch. Any slight variation in the strength, stiffness, or other property of the test specimen, due to a difference in composition or treatment, can thus be quickly and conclusively determined." The Olsen machine used a pendulum balance system of weighing, the most sensitive and accurate automatic weighing device available. The motion of the pendulum rotated the autographic drum, thus measuring the load on the specimen. The stress-strain curve made a record which could be filed for future reference.[23]

The cutting edge of tool steels is of vital concern to our entire industrial pattern. It was determined before the First World War that "various tool steels should be operated at a definite speed for maximum efficiency, depending on their treatment and the material they are to cut. It is essential, therefore, that this speed be determined by test and the machines either operated at a speed calculated to obtain the greatest efficiency from a given tool, or a steel obtained which will give the greatest cutting efficiency at a given speed." A machine put out by Olsen could test drills, taps, dies, and reamers, and it covered all conditions as to speed and feed and measured the four variables of pressure, torque, penetration, and number of revolutions.[24]

[23] T. Y. Olsen, "A New Type of Autographic Transverse Testing Machine for Research Testing or Regular Foundry Practice," in American Society for Testing Materials, *Proceedings,* 11:819–821 (1911).

[24] T. Y. Olsen, "An Efficiency Testing Machine for Testing Drills, Taps and Dies," in American Society for Testing Materials, *Proceedings,* vol. 14, part 2, p. 541–547 (1914); and his "Testing Drills, Taps and Dies," in *Iron Trade Review,* 55:159, 182b (July 23, 1914).

Commenting more broadly on the relationship of the testing machine and the modern foundry, Thorsten Olsen in 1920 explained that the testing machine served two general purposes: "Either to improve the product and thus promote reputation by having a name for supplying the best that is made; or to meet specifications set by the purchaser. There are some manufacturers who go a step further, enter the research or experimental field of testing and equip laboratories with special testing machines, in order not only to test material for tensile or transverse strength, but to test with regard to the particular use to which it is put and also to demonstrate its value in other fields and thereby create a new market."

The general result has been the production of higher-grade materials selling at higher prices. This discussion of various machines suited to the foundry serves as a convenient summary of the work done by Tinius Olsen and his son. They include the universal testing machine; machines for making transverse tests, hardness tests, impact tests, and tension tests; and a machine for testing the efficiency of machine tools.[25]

After 1920 new machines continued to appear on the market.[26] These included a ductility testing apparatus to determine the drawing quality of sheet metal. This machine used a cupping device and at the same time autographically recorded the relations between the pressure and amount of cupping.[27] The list also included a cement tester that used a liquid to break the specimen instead of shot, as was the practice in other machines.[28] In 1930 new cable- and wire-testing machines were announced, and in 1931 Olsen advertised new bend and ductility testers. Olsen also pioneered with a hydraulic universal testing machine put on the market in 1931. This machine,

[25] Thorsten Y. Olsen, "Testing Machines as Related to the Foundry," in *American Machinist*, 53:525–530 (September 16, 1920). For a more detailed account, see his "Recent Developments in Testing Machines," in *Forging and Heat Treating*, 7:66–69, 131–134, and 162–165 (January–March, 1921).

[26] See "Olsen Testing Equipment," in *Machinery*, 32:664–666 (April, 1926).

[27] Thorsten Y. Olsen, "Ductility Testing Machines," in American Society for Testing Materials, *Proceedings*, vol. 20, part 2, p. 398–403 (1920).

[28] Thorsten Y. Olsen, "A New Type of Automatic Cement Tester," in American Society for Testing Materials, *Proceedings*, vol. 20, part 2, p. 408–410.

with lever-weighing and dial-indicating mechanism, combined the flexibility of a hydraulic loading system with the convenience and accuracy of a dial-indicating arrangement.[29] The expedience of this machine for the automobile industry was quickly recognized. In 1938 a British technical journal described a group of new machines, being introduced in England by the Olsen firm, for making and recording stiffness and flexure tests on a variety of materials in the form of thin sheets, strips, rods, and wire. These machines were especially valuable for specimens that were difficult to test satisfactorily by the usual tension, hardness, and ductility methods, and they were small and hand-operated.[30] To meet the increasing demand of foundries, welding and specialty shops, vocational schools, small colleges, and small manufacturers for a moderate-priced hydraulic testing machine, the Olsen firm recently produced one with a capacity of from 20,000 to 60,000 pounds and weighing only about a ton.

But any discussion of the Olsen machines is necessarily either too long or hopelessly incomplete.[31] The reader who wishes to pursue the matter may obtain the catalogues of the Olsen Testing Machine Company. It should be added that many of the machines described above were developed under the direction of Thorsten Y. Olsen. The father ran the firm as a single enterpriser until 1912, when he reached sixty-seven and desired to be relieved of much of the work of direction. He reorganized the business as the Tinius Olsen Testing Machine Company, Inc., with himself as president. Shares to the value of nearly half a million were later issued. The company employed between 200 and 300 men. In 1920, Thorsten Y. Olsen virtually replaced his father as the manager of the firm. Tinius retired in

[29] "Olsen Hydraulic Type Universal Testing Machine," in *Machinery,* 38:305 (December, 1931); see also *American Machinist,* 75:757 (November 12, 1931).

[30] *Engineer* (London), 165:248 (March 4, 1938).

[31] Among the more unusual machines are one designed scientifically to test the strength of human hairs, and another to test the durability of walnut shells — the object in the case of walnut growers being to develop a shell hard enough to permit the piling of sacks in storage but not so strong as to draw nourishment from the meat of the walnut.

1929 and his son has been president since then. Tinius Olsen died in 1933.

VI

It would be difficult indeed to imagine a greater contrast to the modest inventor of the testing machine than Henrik V. von Zernikow Loss, whose technical career in many respects paralleled and rivaled that of Olsen. Loss was born in 1861 at Christiansand, where his father was a merchant. He spent one year in a Christiansand machine shop and entered Horten's Technical School at sixteen. He was graduated in 1878. For a short period Loss held various positions in Norway and then found technical employment with the state railroad service. In 1883, however, he left for America in search of wider experience.[32]

After a few months as a mechanic in Philadelphia, Loss became a draftsman with the Baldwin Locomotive Works there. He had known Carl Barth when the latter was an instructor at Horten, and because of Barth's efforts Loss was employed by William Sellers as an engineer at the Edge Moor Iron Works. There he remained for four years and was closely associated with one of America's greatest engineers. Sellers at the time was spending money with the financial recklessness of a Napoleon — and with equally sensational results. His experiments in steel production led to the use of the rotary puddler, special gas ovens, hydraulic machinery, and other innovations in the rolling mills.[33] For a young immigrant, eager to broaden his technical knowledge and skill, this was an ideal place to complete his education. Of the many experiments conducted during Loss's years with Sellers, the most significant for him was with hydraulic machinery.

Loss, familiar with steel and the new techniques in producing it, accepted a position with one of Andrew Carnegie's firms at Pittsburgh, the Keystone Bridge Company. He obtained this

[32] This and the following paragraphs are based on sketches in the two Horten publications; an able article by Magnus Bjørndal in *Norwegian-American Technical Journal*, vol. 11, no. 2, p. 9 (December, 1938); and interviews with Consul M. Moe of Philadelphia and Bjarne Loss of Lake City, Minnesota.

[33] For a record of Sellers' work see Joseph Wickham Roe, *English and American Tool Builders*, 246–252 (New Haven, 1916).

post because of his special training with hydraulic machinery, and it was the first where, as chief engineer, he assumed absolute technical responsibility. He soon went to the Pencoyd Iron Works of Philadelphia, where his work as an inventor began. Asked to design and build a number of hydraulic machines, he was soon taking out patents in this field. One of his most important productions during this period was a half-million-dollar plant, with hydraulic machinery installed in it, for the production of eyebars.[34]

In 1893 Loss opened his own consulting office in Philadelphia. In a pamphlet which he had issued the year before, he advertised himself as both "consulting engineer" and "hydraulic engineer." He listed among his specialties hydraulic shears for hot and cold materials, punches, rolling machines, straighteners, flanging and bending machines, special presses, valves, riveting machinery, cranes, and accumulators, high-pressure pumping engines, testing machines, and oil-burning furnaces. The same pamphlet also refers to some of his patented machines — among them the Loss lifting and rotating riveter, the Loss patent hydraulic packing, hydraulic forging machines, hydraulic working valves and stop valves, shears, and high-pressure pumping engines.

Thus well launched on the road to a prominent career in hydraulics, Loss was nevertheless unsuccessful in business. In 1895 he became inspector for the construction and operation of passenger and freight elevators in Philadelphia. In this capacity he worked out a system of regulations that were later incorporated into law both by the city and by the state. They were copied in part by New York and Chicago, and eventually became an international standard.

Loss, however, soon returned to hydraulic machinery. In 1898 he was employed as consulting engineer by the Pressed

[34] This machinery and its uses are meticulously described by Loss in a copyrighted study, "The Forging of Eye-Bars and the Flow of Metal in Closed Dies," in *Railroad Gazette*, 25:846, 868, 903 (November 24, December 1 and 15, 1893), 26:5, 43–45 (January 5 and 19, 1894). His conclusion is that, while with iron bars the hammer must do the main part of the work, steel bars are upset in closed dies and should not be hammered.

Steel Car Company at Pittsburgh, then the leading hydraulics plant in the world. There he superintended various lines of production and did considerable designing of machinery until late in 1901. Early in 1902 he was delegated to build hydraulic machinery for the construction of solid steel wheels to be used on steel railroad cars. A new firm, the Schoen Steel Wheel Company, was started in Pittsburgh in May, 1903. In overcoming the difficulties involved in the casting of all-steel wheels, soon to be standard, Loss established a lasting reputation among engineers. For two and a half years he wrestled with his problem; its solution marked a high point in the history of American technology.

VII

Fortunately, Loss's technical development has been well recorded by himself in articles for engineering journals and his speeches before the Franklin Institute and the Engineers' Club of Philadelphia. While interest naturally centers on the steel wheel, other phases of his work are significant from the point of view of his later contribution. As early as 1893, for example, Loss was submitting information of pioneer work in the study of "Resistance of Metals to Shear."[35] "It has often fallen to the writer's lot," he explained, "to have had to undertake the computation and design of heavy shearing machinery. The repeated vexations due to being forced to fall back upon either guesswork or records of former shears . . . led to the inauguration of a series of experiments with the view of finding a guide for engineers in their professional duties." In his conclusions Loss not only pointed out the fallacies inherent in commonly held views, but also gave evidence of having learned much about the quality of iron and steel. In the nineties, while at the Pencoyd Iron Works, Loss placed on the market a riveter which he maintained overcame the tendency toward loss of energy in ordinary riveters.[36]

Loss's subsequent work would have been impossible but

[35] *American Engineer and Railroad Journal,* 67:141–144, 179–182, 247 (March–May, 1893).
[36] Engineers' Club of Philadelphia, *Proceedings,* 11:7 (January, 1894).

for his experiments in the pressing of steel and, in general, the flow of metal. The results of this work were set forth in two speeches given at the turn of the century before the Franklin Institute.[37] In the course of the great industrial competition of the time, he explained in his first address:

> The demands upon our profession became greater and greater, calling for the completion of powerful results inside of shorter and still shorter time. This again meant machines which all had to be quick in action and capable of exerting intense pressures. In the design of motors and machines, simplicity of detail and a small number of parts have always been aims of first importance. . . . And it was this call for the quick exertion of large powers, coupled with the desire to reduce all frictional resistances to a minimum, and also, no doubt, to have a machine that should be under the complete control of the operator — all of which, I say, gave birth to the hydraulic press.[38]

Loss went on to explain that the "vast majority of heavy hydraulic machines hitherto built have been used in connection with processes, the main characteristics of which involve the flow of metals." It was in this field that he had carried on the experiments, mentioned earlier, at the works of the Pressed Steel Car Company, the Pencoyd Iron Works, and the Edge Moor Iron Company. He added:

> A number of years ago, when, in the line of my duties, it came that I had to design some shearing machinery, I naturally looked around for figures regarding the power necessary to sever metals; and this was my first effort in examining existing published results. My examination covered the publications of different nations as well as of different authors. It was, however, all in vain. What little data the scientific literature did reveal was of a crude character, and did not possess accuracy or logical reasons for its deductions. I then commenced to experiment myself; and little by little my field was increased, until it covered all the topics which I have given you this evening.[39]

The results of his experiments, of which detailed records were

[37] "The Pressing of Steel; with Especial Reference to Economy in Transportation," in Franklin Institute, *Journal,* 148:461–473 (December, 1899), 149:26–40 (January, 1900); and "The Flow of Metal," in Franklin Institute, *Journal,* 151:456–464 (June, 1901).

[38] Franklin Institute, *Journal,* 148:462.

[39] Franklin Institute, *Journal,* 149:34.

presented to the institute, covered the whole field of the flow of steel, but led to one conclusion: a lower intensity of pressure is required per unit of section for punching than for shearing.

On March 14, 1901, Loss presented his second paper before the mechanical and engineering section of the institute. Referring to the earlier address, he said:

> The Institute was pleased to send out advance copies of my lecture, thereby securing a very thorough and exceedingly interesting discussion. It gave me great pleasure to know that the major points covered by my work found such liberal and hearty reception, and that the only chapter to which any exception was made at that time was the one covering the resistance to punching. Several of the learned members of this section criticized my assertion that the ordinarily accepted standard ultimate for punching steel should be reduced 30 per cent, or more. . . . There seemed to be a desire on the part of several of the engineers present during the evening to inaugurate a series of individual and separate experiments, with a view of proving or disproving my statements. The burden of the argument seemed to be that punching could not possibly require less power than shearing. . . .
>
> This evening . . . I wish to [state] that the reason for the low ultimate for punching lies in the fact that the punching machinery as hitherto used, and with which experiments have formerly been made, were power punches, possessing great speed of penetration, while the experiments conducted by me have all been confined to hydraulic machines, where the velocity of the flow of metal during the process has been entirely under the control of the operator. Speaking in a general way, I find from observation that the speed during the actual punching was from three to five and six times as great on a power machine as on one driven by water pressure, and herein, undoubtedly, lies the solution of the problem.[40]

In conclusion Loss insisted that "practical punching machinery can be constructed upon certain principles which will allow them to perform 30 per cent. to 40 per cent. more work with the same expense," and, "It is this particular aspect of the case to which I want to call the attention of my fellow members of the Institute."[41]

The authority with which Loss spoke and his independence of traditional theories in respect to punching and shearing attest

[40] Franklin Institute, *Journal,* 151:456–459.
[41] Franklin Institute, *Journal,* 151:464.

to a significant fact about him: an intimate knowledge of hydraulic machinery based upon original experiments and backed by a pioneer courage. It is conceivable that this knowledge might have been of interest only to engineers but for the happy alliance of his skills with American transportation difficulties. Since 1898, when he had been working with the Pressed Steel Car Company at Pittsburgh, he had supervised production of all-steel railway cars. In 1900 he was further identified with the steel car when he was general representative of the Franklin Institute at the Paris Exposition. At this exposition he presented to the International Railway Congress the new pressed-steel car, invented by Charles Thomas Schoen, in the production of which Loss had played an important part.[42] He naturally dwelt on the advantages of the pressed-steel car over one built up from standard shapes, and the superiority of steel over wood as material in the construction of rolling stock. The introduction of the pressed-steel car in the United States had, in fact, almost effected a revolution. If, instead of wooden cars, he argued, lightweight pressed-steel units were used, a great saving would be effected because of reduction in dead weight.[43]

Loss remarked, in concluding his speech at the Paris Exposition:

> The last twenty-five years have been very rich in the development of mechanical ideas of a more or less startling character and wide-reaching effect, but I do not believe, however, there has been any one of greater importance than the advent of the large-capacity, lightweight pressed-steel car, completely revolutionizing, as it has begun to do and will eventually complete, the entire carrying trade of the world. The utility of an innovation has always to be gauged by its results, and remembering that the pressed-steel car is hardly more than two years old, the proof of its title to merit is clearly emphasized when calling to your attention the fact that since the first

[42] Writing some years later, Loss said, "It was my good fortune to have been associated with the birth of the steel car, once an experiment, which quickly, however, became a standard. As the Consulting Mechanical Engineer of the Pressed Steel Car Company, I designed practically all of their plants as well as assisted materially in developing the different details of car construction." See "The Art of Manufacture of Railway Car Axles," in Franklin Institute, *Journal*, 163:1 (January, 1907).

[43] *A New Epoch in the History of Railway Transportation with Special Reference to the Schoen Pressed Steel System in Car Construction* (Philadelphia, n.d.); a pamphlet printed for the Pressed Steel Car Company.

car was placed on its trucks, 26,000 more have found their way as carriers on the different railway systems of the world.

Loss did not realize in 1900 how closely his own reputation was to be linked with the new age of steel in transportation. But two years later significant patents were issued to Loss, one on a "machine for rolling car wheels" and the other for a "hydraulic forging press."[44] The story behind these inventions is best told by their author:

> Railway transportation, with its problems — road bed as well as rolling stock — has in later years claimed more than its share of capital and inventive thought, and as was naturally to be expected, in no other field of engineering have the undertakings been on as large a scale or of more practical and scientific interest to our profession. . . .
>
> Immediately upon the introduction of the 100,000-pound all-steel car, the repair sheets of the different railways showed abnormal accounts, thus on the face of it tending greatly to eliminate the possibility of the adoption of this new innovation in transportation. A little investigation, however, proved that an unexpectedly large amount of the expense was caused by breakage of the wheels, and having no direct bearing upon the car structure proper. . . .
>
> It is also pertinent to recall, in this connection, that both the axle and the rail have been increased in large ratios to sustain the increased duties. The swaying of the heavy steel car, in connection with its increased static load, proved, in many instances, ruinous to the flanges when passing switches or curves; and Mr. Schoen, the inventor and promoter of the steel car, suggested several years ago the possibility of applying a solid steel wheel, because of the fact that no additional weight or thickness could be given to the wheels at the spot where they most needed it, namely: at the root of the flange. In fact, the full economy of the large capacity steel car has never been realized, nor will it be until supported by a wheel, the flange of which will permit increased mileage with a practical elimination of wrecks. With this in view, all data and processes bearing upon the subject were investigated, and, about two years ago, the writer undertook to design for Mr. Schoen a plant to accomplish the purpose with a final result, the success of which is witnessed by the samples herewith shown to you, as well as by the wheels now being tried on the different railways.[45]

The development of the perfect wheel, Loss explained, is "a

[44] Numbers 706,674 (August 12, 1902) and 710,286 (September 30, 1902).

[45] "The Manufacture of Hydraulically Forged and Rolled Solid Steel Railway Wheels," in Franklin Institute, *Journal*, 157:333–354 (May, 1904).

matter of evolution." From the plain cast-iron wheel, engineers moved on to the chilled tread, and later, for greater safety, made a steel tire that could be fitted to the wheel's center. Since the wheel with steel tire required an excessive amount of labor, it was soon clear to Loss that the "ideal product should be made of steel of proper quality, all in one piece and forged and rolled to a perfect finish."

Along with the technical problems involved, the engineer had to keep in mind the question of cost. Loss, using figures obtained from a leading American railroad, showed the great superiority of the steel-tired wheel over its cast-iron rival and indicated its financial advantages. He summed up this discussion by saying that the "average mileage of a cast-iron wheel, when carrying the large capacity steel car, is about 35,000; and . . . the life of a steel wheel should be in the neighborhood of 150,000 miles when based upon the data previously given." Since the steel wheel weighed about 80 pounds less than the cast-iron one, it also effected a saving in dead weight per car of at least 640 pounds.

The processes used in manufacturing the new all-steel wheel may be briefly described. A round ingot, roughly the shape of a wheel but much smaller in diameter and greater in thickness, was placed in a movable die holder of a 5,000-ton forging press. The blank, or ingot, was then reduced in thickness, the hub forged and finished, and the hole punched—"all in one operation." Most of the mechanism was automatic, and hydraulic cranes were attached to minimize labor. The second stage took place in the rolling mill, which had two conical rolls driven by a 1,000-horsepower engine. Electric alarms told the operators "when the thickness of the web and the rim have reached their limit." This rolling process required only one and a half to two minutes. The final step was the coning of the wheel, done in a separate 1,000-ton press provided with the proper dies and handling mechanism.

In this machine the rim is pushed downwards so as to give the proper relation between the edge of the hub and the edge of the

flange. . . . The entire three processes are performed in one heat, and the transportation machinery, from furnace to press, from press to rolling-mill, and again from the rolling-mill to the last press, are all worked out so as to be as near as possible automatic, and will reduce the entire complement of workmen . . . down to about ten or twelve, this number also covering the men who are handling and distributing the cold blanks previous to charging.

In summarizing, Loss called attention to the fact that the solid steel wheel is to be considered "as a forward step in the freight trade." He then took up one by one and met the arguments in favor of the cast-iron wheel. He concluded that the all-steel wheel had become a necessity with the introduction of the steel railway car. With the same disregard for modesty, genuine or false, that characterized all his actions, Loss added that among the epoch-making events in industrial progress "those that refer to transportation on water or land are the greatest of all."

Loss's appraisal of the importance of his work with the steel wheel was seconded by the Franklin Institute. Through its committee on science and the arts the institute investigated Loss's innovation and was sufficiently impressed to recommend that the engineer be given the John Scott legacy premium and medal. The report of the committee is both interesting and significant in bringing out phases not mentioned by Loss.[40] It stated that the "rolling and pressing of the steel wheel . . . is no simple problem. The shape of the wheel renders it difficult to bring a suitable rolling mechanism to bear properly upon it. Furthermore, it is essential that hard, or high grade steel be used in the rim of the wheel, involving powerful mechanism to produce the desired results with the obdurate metal."

Numerous methods had been proposed in the past, both here and abroad, to overcome such difficulties. Several attempts had been made to roll or forge steel car wheels, "but up to recent years, no satisfactory results have been attained in this coun-

[40] The report was printed in abstract in Franklin Institute, *Journal*, 158:398 (November, 1904). The above account was taken from a fuller mimeographed copy of report (no. 2301), "Loss's Hydraulically Forged Steel Car Wheels," in the possession of Bjarne Loss of Lake City, Minnesota.

try." In Germany several mills had been built to roll wheel centers, while the tires were produced separately, but, except for minor uses, the complete wheel as a rolled unit had not been produced.

In 1899, C. T. Schoen had negotiated with German engineers for a mill to roll wheel centers. Loss, as consulting engineer, was to devise the best possible method for producing the finished product. It is clear that the Germans had in mind a mill for rolling only the wheel centers and had no faith "in any attempt to successfully roll the rim as well as the centre of the car wheel." The report described Loss's hydraulic press as "an excellent piece of mechanical design" embracing "several novel and original features," and cited as an example of originality the independent hydraulic ram which both forged and punched and could be "operated in conjunction in exerting intense moulding pressure on the work." It also commended the "ingenious method" of releasing and withdrawing the punch from thick, hot metal and also the arrangements for discharging the punchings and taking the compressed blank out of the die. The rolling mill that Loss set up was "similar to" the original German mill for which Schoen had purchased designs, but many new features had been added to this design "to permit the rolling of the flange of the wheel, making a much more powerful mill and applying much greater motive power than originally contemplated." Because of the earlier German mill, however, the committee cautiously preferred to "give precedence to the subject of the hydraulic press." Because of its novel features, "so well adapted for the intended purpose," and the "mechanical skill displayed by Mr. Loss in its design," the committee believed that he had "accomplished a desirable advancement in the methods of producing solid, rolled steel, car wheels."

VIII

Loss's technical career did not end with the solid steel wheel, which was soon to become standard with leading railroad companies. It was found that the use of steel cars involved increased

axle breakage. In 1906 Loss insisted that "the method of manufacture as now in vogue is decidedly unfinished and crude, involving large wastes, both in material and labor." The important thing, he stressed, was to get away from hammering the steel in the axles.[47]

It has already been noted that while Loss was employed by the Pencoyd Iron Works, he had designed an upsetting machine for bridge eyebars, "adopting in this connection a system of dies, which, generally speaking, may be considered to consist of a closed box, enveloping a stationary bar and arranged to move longitudinally against its free end. This machine, as well as a larger one—built later on the same lines—have been both successfully operated for years by the American Bridge Company, and as a result of my work in this direction, came the suggestion of embodying the upsetting principle to a billet with the view of producing an axle." The machine intended for this purpose consisted of "a central stationary die, horizontally split, and two moving end dies similarly divided, each of which contains a cylindrical heading die." The upsetting of a steel bar, Loss explained, was "simply a forging process, conducted in a longitudinal direction, and if properly performed, will similarly condense and refine the metal. Like any closed-die method, it is very superior to the use of a hammer." He denied that upsetting hurt the steel, as was maintained by some engineers who harked back to the days of iron. Loss based his reasoning on experiments conducted at the American Bridge Company.[48]

At the age of about forty-nine, Loss retired from his engineering work. He continued, however, to serve as consulting engineer on several important undertakings for the Carnegie Company and the Baldwin Locomotive Works. Unmarried and socially ambitious, he spent the last forty years of his life at the University Club in Philadelphia. Though he lived in this country nearly sixty years, he was never naturalized. He devoted about six months of each year to traveling in a grand

[47] "The Art of the Manufacture of Railway Car Axles," in Franklin Institute, *Journal,* 163:1–30 (January, 1907).
[48] Loss, in Franklin Institute, *Journal,* 163:1–30.

manner about Europe; the other six were spent in Philadelphia and Atlantic City.

In May, 1938, Loss left New York City on the last of his annual trips abroad. He died in Oslo on June 28 at the age of seventy-seven. During his last years his obsession had been to leave a million crowns to his native city of Christiansand. His large fortune, however, was pruned away in the great depression. Most of what was left, about $192,000, went into the von Zernikow Loss Fund. The interest on this sum, when it amounted to 30,000 crowns per annum, was to be used for the beautification and cultural enrichment of Christiansand.[49]

IX

Mauritz C. Indahl's name is to printing and the monotype what the name Olsen is to scientific testing, but it is improbable that history will grant the honors that Indahl deserves. It was Tolbert Lanston who actually conceived the idea of the monotype. To Indahl went the more pedestrian task of making it a practical machine, of giving form to an idea. To this task he devoted his entire technical career in Philadelphia.

Immigrant Americans have figured prominently in the recent history of printing, their major contributions being in the field of typesetting by machine. While it is true that William Church of England took out the first patent on a typesetting machine in 1822, it was Ottmar Mergenthaler, a German-American watchmaker of Baltimore, who worked out the principle of setting and casting type in virtually one operation. Mergenthaler's linotype, patented in 1885, was put into use the following year, with results well known in the cultural and economic fields. This machine, now widely used, casts a line of characters upon a single lead slug.

The second such major contribution—Lanston's monotype machine—appeared in 1887 and was perfected by the gifted Indahl in the years that followed. The monotype, as dis-

[49] Much of the writer's knowledge of Loss, apart from the purely technological phases, has come from sources already cited, various Norwegian newspapers, Consul M. Moe in Philadelphia, and Bjarne Loss, a nephew of the engineer.

tinguished from the linotype, casts single characters, any of which may be replaced without recasting the entire line. Lanston, Indahl, and Bancroft "separated the processes of composition and casting, introduced perfect line-justification, and abolished distribution."

> Greater output is obtained, and the range of the product is practically unlimited. Owing to the great variety of characters which may be composed at the keyboard, also to the fact that the individual characters are cast to perfect precision in regard to height and width, and again to the fact that corrections are so simply made by hand, the production of the Monotype machine has restored the quality of printing to that high standard of excellence which existed when typography was at its best.[50]

Mauritz Indahl was one of those mechanical geniuses who began early in life to model, first with wood and later with metals, objects ranging from toys to complicated devices.[51] From his father's farm in Toten, where he was born in 1868, he journeyed to Horten to receive formal training in the line of work for which he showed such precocious tendencies. After his graduation in 1891, he worked for a short time as a machinist in Christiania before setting out in the following year for Philadelphia. Carl Barth assisted Indahl, as he had Loss, in securing work with William Sellers. When the Sellers firm contracted in 1895 to build 400 typesetting machines for the Lanston Monotype Machine Company of Washington, Indahl was made assistant to the mechanical engineer, J. Sellers Bancroft, "in the work of converting the inventions of Tolbert Lanston into practical form. In 1900 the Monotype machine was offered to the trade."[52]

When, two years later, the Monotype Company moved to Philadelphia and began to manufacture its own product, Bancroft became chief engineer for the company and Indahl his principal assistant. Bjørndal writes that Bancroft "insisted on

[50] *Printing in the Twentieth Century, a Survey,* 47–49 (London, 1930); reprinted from the *London Times,* October 29, 1929.

[51] The writer is especially indebted for details of Indahl's life to Magnus Bjørndal for his brief but able discussion in *Norwegian-American Technical Journal,* vol. 14, no. 1, p. 24 (May, 1942); and to Mrs. Indahl, whom he interviewed in 1941.

[52] *Printing Equipment Engineer,* 61:30 (February, 1941).

redesigning the entire machine before proceeding with its manufacture, and it was Indahl's good luck to be selected as the designer for this job."[53]

Indahl's design resulted not only in a larger machine but in one with complete typecasting arrangements which were essentially those of the present-day monotype. When Bancroft died in 1919, Indahl was made chief engineer and he continued to work modestly and single-mindedly on methods for improving the monotype. Two days before he died, in January, 1941, he finished "important drawings of a part of the mechanism of a newly improved typesetting machine."[54]

The full cultural significance of the monotype can better be grasped when its operation and use are more fully understood and contrasted with the more familiar linotype. The monotype actually consists of two machines, the keyboard and the caster.

> The keyboard operator depresses keys similar to those on a typewriter, but instead of printing letters the Monotype keyboard perforates a paper ribbon with a combination of two holes for every letter. With each key depression the paper ribbon is automatically advanced, and at the end of each line special perforations indicate (to the casting machine later on) the exact thickness of spaces which must be cast to make the line correct to a uniform length. When the copy is finished, or when a spool is completed, the perforated ribbon is transferred to the casting machine, where it is automatically cast, and the lines are arranged in proper order ready for proofing.[55]

The monotype not only turns out a high-quality product at great speed, but it can also produce composition of an intricate kind. Its type ranges from the smallest to the largest and a line runs up to 10 inches in length. Timetables are frequently composed on the monotype, and attachments permit casting of type for handwork up to 72 points, in addition to leads, rules, and ornaments. It has been called "a complete foundry machine as well as a composing machine."[56] While few newspapers are set by monotype, it is "used to a large extent in the

[53] In *Norwegian-American Technical Journal*, vol. 14, no. 1, p. 24.
[54] *Printing Equipment Engineer*, 61:30 (February, 1941).
[55] *Printing in the Twentieth Century*, 47–49.
[56] *Printing in the Twentieth Century*, 49.

printing of magazines, books, and in commercial printing of all kinds. Almost every newspaper plant of any size has at least one monotype caster to cast up 'sorts' of display types, leads, slugs, rules and other materials needed in every composing room." While the monotype may not be as practical as the linotype for setting regular news matter, it has many advantages in the printing of folders, advertising booklets, magazines, books, and in general commercial work. The type is "always new and fresh and does a cleaner, better printing job." Many advertisers have their ads set up by monotype and then supply the newspapers with an electrotype or mat of the advertisement. Still another advantage — which applies to book work — is the fact that the perforated ribbons can be stored indefinitely and can be used again and again.[57]

It is extremely difficult in the case of a machine like the monotype — the product of several brains — to determine which are the specific contributions of one man. But it can be stated definitely that when the features devised by Indahl are removed, very little is left of the machine as it is today. The writer has studied a list of 107 patents issued in this country to Indahl; most of them pertain to the monotype; many were issued jointly to Indahl and Bancroft. Bjørndal specifically mentions as improvements made by Indahl the "new standard keyboard, the visible type casting mechanism, the brilliant line casting matrixes which make it possible to cast lines in any length, the ninety scale, the automatic device which cuts off and assembles the cast pieces, the improvement which permits the exact casting of the famous type design created by Mr. Frederic W. Goudy, and recently a new headline casting machine which can produce letters in any size required." [58] A trade publication wrote at the time of Indahl's death:

[57] Kenneth E. Olson, *Typography and Mechanics of the Newspaper*, 111–117 (New York, 1930). Other accounts of Indahl and the monotype may be found in *Engineer* (London), 117:197–199, 228–230, 255–257 (February 20–March 6, 1914); *Decorah-posten*, April 1, 1927; *75 års biografisk jubileums-festskrift, Hortens tekniske skole*, 161; and Wong, *Norske utvandrere*, 141–144. Olson's book is quoted by permission of D. Appleton-Century Company, Inc.

[58] *Norwegian-American Technical Journal*, vol. 14, no. 1, p. 24 (May, 1942).

It has been said that Tolbert Lanston had thought of the Monotype as a mechanical means for setting type, having no conception that the principles involved in his hot-metal typecaster would eventually form the basis for the creation of other machines for casting type in sizes up to 72 point, and to make rules, decorative borders, and leads and slugs in strips, which would be used in the then unknown non-distribution methods.

Indahl played an important part in expanding the scope of the Monotype typecaster to make display type for hand use. This machine was put on the market in 1905. He also participated in the design and development of the first strip lead, slug and rule casting machine introduced in 1914. He was inventor and designer of the Monotype Material Making Machine introduced in 1921, and the giant caster, first marketed in 1926.

The same journal adds that Indahl was active in the design and manufacture of the lithographic photomechanical apparatus constructed after his company bought the assets of the Directoplate Corporation in 1932; this work was carried on with William C. Huebner and Joseph P. Costello.[59]

In 1940, Indahl received an award from the National Association of Manufacturers for being "A Modern Pioneer on the Frontier of American Industry." The citation read on this occasion stresses the most significant feature of his work, "the application of engineering to machines to attain the speed, versatility and accuracy of construction requisite to commercial success in a highly competitive field." Together with Tinius Olsen and Henrik V. von Zernikow Loss, Indahl added a vital chapter to the old Philadelphia story begun by Benjamin Franklin and fostered by the institute bearing his name. Like his fellow Horten men, he was also a sturdy representative of the new Philadelphia which is the home of immigrants, of industry, and of technological progress.

[59] *Printing Equipment Engineer,* 61:30.

SPANNING AMERICA'S RIVERS

THE development of the North American continent and the building of bridges are twin stories that frequently intertwine. From the earliest colonial days to recent times, the explorer and the frontiersman found the crossing of rivers one of the greatest obstacles in the westward movement of population. But it was the nineteenth-century revolution in transportation, with its development of improved highways and of railroads, that made bridges of high quality an absolute necessity. Later, with the coming of the automobile, the truck, and the bus, highways became great arteries of freight and passenger transport and the result was a veritable epidemic of bridgebuilding. The growth of cities and the concentration of transportation at these points have been accomplished only by spanning the waters that in almost every instance penetrate or surround the metropolitan areas. As a result of the daring and the skill of American engineers, highways and railways radiate from key centers of business within the cities and into the surrounding countryside—and motor vehicles, streetcars, trains, and pedestrians thus move easily across our inland waters.

The names of such distinguished men as Ammann, Lindenthal, Modjeski, Pihlfeldt, and Cappelen call to mind the debt owed to the foreign-born and foreign-trained engineer in the remarkable story of bridgebuilding. Of the immigrant engineers, those from Norway played a role—partly because they became identified with bridgebuilding at vital transportation points—that seems entirely out of proportion to their numbers. Notably

in Chicago and in the Twin Cities, but also in Seattle, New York City, and elsewhere, bridges of all kinds serve as New-World memorials in steel and stone and concrete to men trained in the schools of northern Europe.

I

No name among the Norwegian-American engineers suggests a more brilliant bridge career than that of Thomas G. Pihlfeldt. Born in 1858 at Vadsø, Pihlfeldt attended school in Trondhjem, and in Hammerfest and Christiania. He received all of his technical training, however, in the famous polytechnicums at Dresden and Hanover. After completing his studies, Pihlfeldt left at once for America, and arrived in Chicago in August, 1879. Despite the city's rapid growth after the fire of 1871, Pihlfeldt was unable to find anything except a job as a machinist. For several years he was none too happy in Chicago, but later he obtained positions as draftsman and designer with several private firms. And in September, 1889 — ten years after his arrival in America — he entered the bureau of maps in the public works department of the city of Chicago. In 1894 he was transferred to the bridge division of the engineering bureau, and in 1896 he was made principal assistant to the city bridge engineer. His rapid climb culminated with his elevation in 1901 to the office of chief engineer of bridges, a position he held until his death in 1941 — after more than fifty-one years of loyal and distinguished service to a restless and growing city.[1]

Interest in Pihlfeldt hinges mainly on his work in spanning Chicago's rivers and thereby solving the chief transportation problem that confronted the sprawling community on Lake Michigan. The story of Chicago's bridges is the story of Chica-

[1] Pihlfeldt had a strong aversion to recounting his life story, except for the professional aspect of it, which he considered an open book. The above record is culled from the following: *Nordisk tidende,* March 21, 1918; *Decorah-posten,* August 5, 1927; *Norwegian-American Technical Journal,* vol. 1, no. 1, p. 3 (February, 1928); *Who's Who in Chicago and Vicinity,* 775 (Chicago, 1931); A. E. Strand, *A History of the Norwegians of Illinois,* 451 (Chicago, 1905); *Nordmands-forbundet,* 24:98 (1931); *Skandinaven,* January 14, 1938, and January 28, 1941; *Scandia,* April 7, 1938; *Chicago Tribune,* January 24, 1941; *Journal of the Proceedings of the City Council of the City of Chicago, Illinois,* 4173 (Chicago, 1941).

go itself, and Chicago's history constitutes an important chapter in the history of American transportation.[2]

When the early French explorers came to the lower end of Lake Michigan they found a muddy creek, later called the Chicago River, flowing eastward into the lake. Close by the headwaters of the creek they also discovered the Desplaines River, which flows westward. When—as frequently happened—the Desplaines and the creek came together, they formed a connecting link between the drainage areas of both the Mississippi and the Great Lakes. The early explorers immediately recognized that here was "a connecting link in a possible trade route from the valley of the St. Lawrence to the valley of the Mississippi." It was clear that if the Chicago River were connected with the Desplaines by a canal, "it would be possible to transport merchandise from the Atlantic up the St. Lawrence into the Great Lakes and from the Great Lakes into the Mississippi, and so on to the Gulf of Mexico. In fact, here was a water route extending for thousands of miles down through the very heart of one of the richest lands on earth."[3]

A key link in the trade routes of the Northwest and also the site of a trading post, the Chicago River remained for over a century the only street in the primitive settlement that grew up on its shores. Most of the early settlers built their homes in an area south of the main branch and east and west of the south branch of the river. The need soon arose for a more convenient means of crossing the river than a canoe or boat; as a result a ferry was put into operation in 1829 at the present site of the Lake Street Bridge. For 6½ cents a man could cross on this rope-operated scow; for 12½ cents he could take his horse with him. In 1834, one year after the incorporation of Chicago as a town, a primitive movable bridge—the first of many—was

[2] Since this chapter was written a comprehensive account of Chicago bridgebuilding has appeared: Donald N. Becker, "Development of the Chicago Type Bascule Bridge," in American Society of Civil Engineers, *Proceedings*, 69 (I): 263–293 (February, 1943). Becker is present engineer of bridge design for the city of Chicago.

[3] Loran D. Gayton, "The Chicago River and Its Crossings," Armour Tech Radio Programs, Station WJJD (Chicago), January 15, 1933; copy in the office of the city engineer. Gayton, then assistant city engineer in Chicago, writes well and authoritatively. He later became city engineer.

built at Dearborn Street. In 1840 another was added at Clark Street, and by 1849 there were bridges at Wells, Randolph, and Kinzie streets as well.[4]

These bridges served the needs of the time, but the flood of March, 1849, carried them all away and wrecked most of the shipping in the main and south branches of the river. Before the shipping interests recovered from the damages of this flood, new bridges began to replace the old. And it was absolutely vital that they be built. The opening of the Illinois and Michigan Canal in 1848 gave the grain-growing country of central Illinois access to the Chicago port facilities. At the same time railroads were also being built in the area. Railroads and canals increased the commercial activity in Chicago and stimulated the city's industrial growth. The shipping interests became especially powerful, and as they grew in strength they were increasingly insistent that all obstructions to traffic in the river be removed and a new type of bridge designed to take the place of the clumsy and inefficient structures then in use. The result was the swing bridge.[5]

The great fire of 1871, which wiped out the entire central part of Chicago, also destroyed the bridges across the main river at Rush, State, Clark, and Wells streets, the one across the north branch at Chicago Avenue, and those across the south branch at Adams, Van Buren, and Polk streets. By the summer of 1872 most of these were replaced by swing bridges of rather substantial build. The year 1872 also saw the start of a new era in railroad construction. New lines came into being almost overnight and reached out in all directions from the city. As a result Chicago eventually became the greatest railroad center in the world. As traffic across the branches of the river increased, there developed a strong demand for wide bridges. This demand grew as the small sailing vessels gave way to steam-driven craft, which, because of their broad beams, required a wide channel if they were to ply the river. The old swing

[4] Gayton, "The Chicago River."
[5] Gayton, "The Chicago River."

bridge, with its inconvenient center pier, could no longer serve. The need was for wide crossings that could be quickly opened and closed and would not obstruct river traffic.

The first attempt to eliminate the center pier was a jackknife bridge built in 1891, at Weed Street. Supported from a pile foundation near the shore, this bridge had no center pier.

> The roadway was composed of two parts with a hinge and in opening to allow the passage of a vessel, this bridge folded up like a jack-knife. It was not at all similar to the present bascule bridge. This bridge was an ingenious contrivance, but due to its many joints it got out of order very easily and was expensive to maintain.
>
> Mr. Thomas Pihlfeldt, a young engineer in the Bridge Division at that time, remarked that this jack-knife bridge was a "combination folding bed and mouse trap." [6]

An attempt to eliminate the center pier was made in 1894—a so-called vertical lift bridge over the south branch of the river at Halsted Street. Its awkward towers and great expense made it impractical. The need to meet the demands of both the shipping and land interests produced still another type of bridge, patented by William Scherzer and known as the rolling lift bridge. One was erected in 1895 over the south branch of the river at Van Buren Street. Like the others unsatisfactory, this bridge did, nevertheless, mark a great improvement over earlier ones. The main objection to it was that during the opening process the load shifted position on the pier. After a careful study of movable bridges, the Chicago engineers finally decided upon the trunnion bascule bridge as best suited to meet the problem.

The forerunner of the bascule bridge was the hinged leaf over a castle moat. There had been no progressive development of it since the medieval period, because the operating power and building materials needed for a span of any length were not available until recent times. Consequently, the center-pier swing bridge enjoyed a long popularity. At the end of the nineteenth century, however, with the introduction of steel and electric power, it was possible to meet the demand for better

[6] Gayton, "The Chicago River."

and larger movable bridges. The word *bascule* is French, meaning "see-saw"; and "hence a Bascule Bridge means a balanced structure where the balance or counterpoise lowers as the roadway rises. Such is truly the case with the present day [*Chicago-type*] bascules for they are balanced in all positions and revolve about trunnions or pins located near the center of gravity, the counterweight sinking into a tailpit as the roadway swings into the air."[7]

The question naturally arises, why, specifically, does the Chicago River today lend itself so well to the bascule bridge? The answer has been well summarized:

> The reason for this can readily be seen by considering the local conditions. To begin with it is well to recall the character of the Chicago River. Its main branch cuts through a portion of the business district; hence hundreds of thousands of people daily must pass over it to reach homes or places of business. Its north and south branches reach miles out into the industrial sections of the city and there great manufacturies have their docks and loading ships. Consequently, the largest lake steamers must ply almost its entire length. Furthermore, the concentration of business in the comparatively small area of the loop has made land so valuable that every foot of ground up to the river's edge must be utilized, and so the river has become bound in by docks to a width of approximately 200 feet for the greater part of its length.
>
> In view of these conditions, it is simple to list the advantages of the bascule type bridge as against the swing bridge for this district:
>
> (1) No center pier to obstruct navigation. . . .
>
> (2) Minimum space is required and approaches are easily built.
>
> (3) Need not be fully opened for passage of small vessels; swing bridge must always be fully opened.
>
> (4) Bascules have a shorter time of operation.
>
> (5) In cities like Chicago where wide roadways are necessary, a swing bridge of considerable road width narrows the channel when open.
>
> (6) Bascules may be built side by side for railroad use without interference.[8]

Because of these advantages and the fact that many of the

[7] Gayton, "The Chicago River."

[8] Earle G. Benson, "The Development of the Chicago Type Bascule Bridge," in *Armour Engineer,* 22:81–83, 105 (March, 1931). Benson was, at the time of writing, bridge design engineer for Chicago.

old swing bridges were beyond practical repair, the city of Chicago decided in 1900 to replace swing bridges with bascules. Competitive drawings were solicited for a bridge over the Calumet River at Ninety-fifth Street, where conditions are about the same as those on the Chicago River. John Ericson, then city engineer of Chicago, at once submitted three designs, with the request that they be presented for criticism to a board that included one bridge engineer and two mechanical engineers. In his letter transmitting the plans Ericson gave credit to Edward Wilmann, a Norwegian who was then city bridge engineer, Karl Lehmann, Alexander von Babo, and Thomas Pihlfeldt, for valuable assistance in bringing out the designs.[9] Three Norwegians thus co-operated on this project.

A bascule type of bridge met with the approval of the board, and they selected one of Ericson's designs.[10] The approved three-truss bascule bridge, according to an account by Pihlfeldt, had a total width of 60 feet, the trusses being 21 feet center to center; the sidewalks were carried by 9-foot cantilever brackets. The machinery for operating each leaf was placed under the approach roadway, and the leaves were operated by means of a pinion gearing rack on the curved tail end of each truss. Along the top of the abutment extended a shaft carrying three pinions and having two sets of driving gear. Each set of driving gear was powered by an electric motor of 38 horsepower. "The machinery is so designed that the opening of the bridge from the moment it is closed to traffic to the moment when the leaves reach their highest position, will not take more than one minute in calm weather or two and one-half minutes with a seventy-mile wind blowing in a direction unfavorable to the operation of the bridge." Two bridges were planned for erection—one at Ninety-fifth Street over the Calumet River and the other at Division over the north branch canal.[11]

[9] *Engineering Record,* 42:50–52 (July 21, 1900).

[10] *Engineering News,* 45:18 (January 10, 1901).

[11] Thomas G. Pihlfeldt, "Designing," in *Mayor's Annual Message and the Twenty-fifth Annual Report of the Department of Public Works to the City Council of the City of Chicago for the Fiscal Year Ending December 31, 1900,* 87–91 (Chicago, 1901).

II

The Chicago-type bascule soon took its place in bridge history. In an attempt to improve navigation and to increase the flowage capacity of the drainage canal, the city decided to replace 12 swing bridges with as many bascules.[12] The first to be erected was at Clybourn Place (later Cortland Street). Opened to traffic in May, 1902, this bridge — new to America — became a model for others. It was 120 feet long, center to center of piers, and gave a clear channel of 100 feet between pile protection works. Under the supervision of John Ericson, city engineer, the design was prepared for the most part by Karl Lehmann and Edward Wilmann. The work of construction was completed under Pihlfeldt, who succeeded Wilmann as bridge engineer.[13]

There is no indication in the records that Pihlfeldt participated prominently in the design and construction of the Ashland Avenue Bridge across the west fork of the Chicago River's south branch. Announced and described in the spring of 1901, this bridge was actually completed in the fall of 1903, after Pihlfeldt had assumed responsibility for bridge work. It opened and closed in 42 seconds.[14]

The Division Street Bridge was perhaps the first to be wholly designed and built under Pihlfeldt's leadership. Opened to traffic on June 8, 1904, this double-leaf bascule gave a 160-foot clear opening across the Chicago River. Its concrete substructure was carried down 23 feet below the water level and was supported on piles driven to solid rock and cut off 21 feet below the water. Concrete had been poured inside a mud cofferdam. In several respects unusual, the Division Street Bridge had two independent operating houses — one for each leaf — and contained 700 tons of structural steel and 100 tons of machinery.[15]

[12] *Engineering News,* 45:75–79 (January 31, 1901).
[13] *Railroad Gazette,* 34:550 (July 11, 1902).
[14] *Engineering Record,* 43:392–394 (April 27, 1901), and 48:434–436 (October 10, 1903).
[15] *Engineering Record,* 50:215 (August 20, 1904).

The next bridge of importance was a double-deck, double-leaf bascule across the Chicago River at Lake Street. With a 245-foot span, this bridge carried a railroad on the upper deck and a roadway with streetcar tracks and sidewalks on the lower. During erection the elevated had to be kept in operation over an old swing bridge; this added not a little to the difficulties met in construction. When finished, the new bridge provided a clear width of 195 feet. Steel sheetpile cofferdams had to be used in placing the main piers, which were supported by sub-piers carried to bedrock. In addition to being one of the heaviest bascules ever built, it was the first to eliminate piling and to find support on cylindrical caissons resting on solid rock, in the same manner as the skyscraper.[16]

Not a little interest was shown in the Michigan Avenue Bridge over the Chicago River. The bridge was one of the main items in the Chicago Plan and it was first operated in May, 1920. Incorporating many new features of construction, this bascule was considered noteworthy for its great size and the heavy traffic it would have to carry. It was believed to be "the only double deck bridge ever built having highways on both levels in order to provide for a separation of fast and slow traffic." The Michigan Avenue structure was "the most important part of the widening and extension of Michigan Avenue between Randolph St. and Chicago Ave. to afford a wide and direct thoroughfare connecting the business district with the north-side section of the city, an improvement which eliminates the former circuitous and congested route crossing the old Rush St. swingbridge." Viaduct approaches connected the street level of the avenue with the upper roadway of the bridge; the lower roadway was for the heavy and slow traffic between terminals, industries, and docks near the river. The bridge provided a clear channel width of 220 feet and, because of war department requirements, allowed navigation headroom of 16½ feet from the water level for 80 per cent of the channel width when the bridge was closed. Believed to be the heaviest bridge in Chicago, prob-

[16] *Engineering News*, 74:876–879, 934–936 (November 4 and 11, 1915).

ably the heaviest of its kind in the world, it weighed about 13,400,000 pounds.[17]

In the many interviews granted by Pihlfeldt during his long term as bridge engineer, he spoke most frequently of the erection of the Wells Street Bridge. His quiet pride in this achievement is understandable, and it is only natural that he himself should have left the best record of its construction. Before the Western Society of Engineers in Chicago, he spoke at length of the bridge's historical background. He explained that whenever a bascule was being constructed to take the place of a center-pier bridge the traffic "was diverted and distributed over adjacent bridges in the territory. Or, if the thoroughfare happened to be a very busy one, a temporary bridge on pile bents . . . was constructed far enough away from the permanent bridge site to give ample room for free and efficient construction operations."[18]

Early in 1909 the war department, which has control of navigation on rivers, asked that the swing bridge on Lake Street be removed.[19] Pihlfeldt explains:

> The order also stipulated the replacement of the center pier bridge, with a bridge having a clear opening for navigation, not less than the distance face to face of abutments at datum of the center pier bridge. . . .
>
> The question then arose as to how to take care of the Oak Park Elevated Railroad, using the other deck without an encroachment on the then existing facilities for vessel movements, during construction of the new bridge. . . . It would have been possible to reinforce and double-deck Madison Street Bridge, with a temporary elevated structure east of the river, connect to the Market street spur, and west of the river in Madison and Canal streets connect to the main line in Lake street. . . . This resulted in a vigorous protest from property owners along Madison street whose frontage

[17] Hugh E. Young, "Chicago Bascule Bridge—Design and Operating Features," in *Engineering News-Record,* 85:508–514 (September 9, 1920). See also *Engineering News,* 70:116 (July 17, 1913) and *Engineering News-Record,* 83:210–213 (July 31, 1919).

[18] From a speech made by Pihlfeldt on October 10, 1921, and published under the title, "The Wells Street Bridge," in Western Society of Engineers, *Journal,* 27:59–64 (February, 1922).

[19] This was part of a fixed plan established in Chicago by the federal government to replace all center-pier bridges with those of the bascule type.

consent was necessary . . . and the proposition was consequently dropped. . . .

Let us for a moment consider the immense volume of traffic over our bridges, particularly the double-deckers. . . . The figures are, of course, averages, and cover the period from 7 in the morning until 7 at night, or 12 hours. We find as follows: Eight hundred and fifty teams, 1,130 autos, 1,000 trucks, 1,050 street cars, 7,000 pedestrians, 1,000 Elevated trains; and let us not forget that these bridges are open for vessels on an average of 300 times a month. . . . I think you will agree with me that the task of maintaining this enormous volume of traffic over a bridge, when a new bridge is constructed under and over it, is not so very easy after all, and I do not think you will be surprised when I confess that there were times when I thought myself stumped. In analyzing the situation at Lake street it occurred to me that by abandoning all the traffic on the lower deck and only maintaining the elevated trains, which could not be diverted . . . our problem would be materially simplified, and that actually proved to be so. Shutting off the traffic on the lower deck enabled us to remove the sidewalks and their brackets, pull the piles in the pier protection, redrive them closer to the center pier, which again allowed us to construct cofferdams and still maintain the same width of the two draws as before. With proper temporary supports for the end of the swing bridge and the elevated structure we had fairly good room for the construction of the foundations, and with that completed we felt that we were out of the woods.[20]

Encouraged by the success of the Lake Street project, the bridge division went to work on the Wells Street Bridge. The engineers were instructed to design and build the new bascule in such a manner that the full volume of traffic could be maintained over the existing swing bridge with a minimum of inconvenience to the public. The old Wells Street Bridge, built originally in 1888 and remodeled in 1896, carried ordinary street traffic, including streetcars, as well as the double track load of the Northwestern elevated railroad. A new double-leaf, double-deck trunnion bascule bridge took its place, exceeding in weight any of the city's two-truss bridges thus far built. In explanation of how traffic disturbance was avoided, Pihlfeldt said:

In order to make possible the maintenance of traffic on the lower deck, it was necessary to provide temporary supports for the road-

[20] Western Society of Engineers, *Journal*, 27: 59.

way and sidewalks on the fixed approaches to the old bridge, so that the new substructure could be placed thereunder. For this purpose, steel girders and trusses were provided, and the floor loads were carried by them to pile clusters outside of the limits of the new work. The construction of the greater part of the cofferdam could then be accomplished without disturbing the old bridge. During the remodelling of the lower deck on the fixed part the street was closed to vehicular traffic only one roadway at a time, and very slight inconvenience was caused thereby.

Provision for driving those portions of the cofferdam directly under the swing bridge was made by stopping traffic between the hours of 1 A.M. to 4:45 A.M. for a period of about two weeks for each dam, and swinging the span to the open position during that time. After the completion of the cofferdam, the excavation for the counterweight pits and sub-piers was in order and this was followed by the placing of the concrete and steel for these parts of the structure.

To effect the erection of the bridge superstructure, without interfering with traffic, it was necessary to omit floor beams, stringers and bracing in two panels, so that with the bridge leaves in the open position, vehicles and elevated trains could pass through the structure with a clear space from truss to truss.

On the 2nd of December we expect the work on the superstructure to have progressed so far as to bring it to the last leg of construction, that of changing from the old swing bridge to the new bascule. . . . It is expected that the interruption of elevated railroad traffic will not exceed 48 hours. In other words, if nothing unforeseen happens, traffic on the old swing bridge will be shut off at 8:00 P.M. Friday, Dec. 2, and traffic resumed on the new bridge Sunday evening, Dec. 4.[21]

Pihlfeldt might have been writing in the past tense, so accurate was his timetable. The Wells Street Bridge, connecting the north and south sides of Chicago, was lowered and put in operation on December 4, 1921 — according to plan. When the new bridge was nearly complete in upright position, preparations were made for removing the old bridge and lowering the new. All traffic on the old crossing stopped at 8:00 P.M. on Friday, December 2.[22]

The old bridge was swung to the midstream position over the center pier. Timber bents, supported by piling driven in the river bed, had

[21] Western Society of Engineers, *Journal,* 27:60.

[22] Another account of plans for putting the bascule in service is in *Engineering News-Record,* 87:606 (October 13, 1921). See also *Public Works,* 53:174–176 (October, 1922).

> been previously placed to support the ends of the old bridge when the center section should be removed. At midnight on Dec. 2, cutting out the center section of the old bridge was begun.
>
> Upper members were cut nearly through and allowed to remain in place. With the coming of daylight removal of the old steel members was begun. A concrete barge upon which was mounted a derrick similar to the one used in handling the new structural steel was anchored near the old bridge. A scow was brought alongside for the reception of the steel members as they were removed. . . .
>
> Attachment was made to a nearly severed member and the derrick cables tightened. Then the cuts at each end were completed and the free member lowered into the scow. In this way a section 80 ft. wide was removed from the old bridge by 4 P.M., Sunday, Dec. 4.
>
> During the cutting away of the old bridge, the omitted portions of the new structure were rapidly erected. . . . At 5 P.M., Sunday, Dec. 4, both leaves of the new bridge were lowered in place. The two leaves met in the center with less than ¼ in. total error. . . .
>
> As soon as the leaves were lowered in place construction gangs of the elevated railroad company started to lay track over the bridge. This was completed and elevated service was resumed at 7 A. M., Dec. 5, after an interruption of only 59 hours.[23]

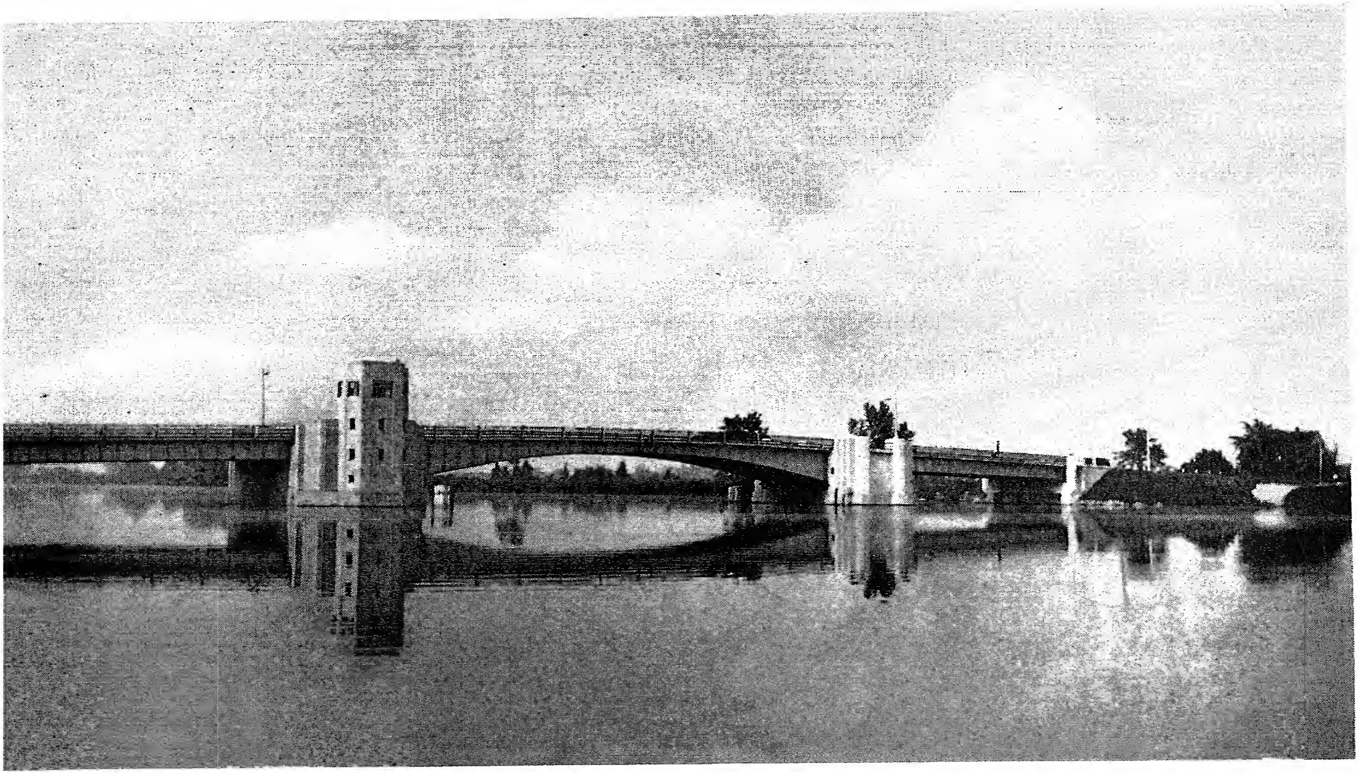
Installation of electric signals and warnings and of new approaches soon completed the work. The result was a bridge with an over-all length of steel structure, from abutment to abutment, of 385 feet; this gave a clear channel of 220 feet.[24]

Later, in looking back on his career as bridgebuilder, Pihlfeldt regarded the erection of the Lake Street and Wells Street double-deck bridges as his greatest achievements. He was pleased with the manner in which the new structures had been built complete near the shores, except for a few stringers at the ends. He explained that the old swing bridge had barely been burned out with torches when the new leaves were allowed to fall in place. "The men in the drafting room said 'The Old Man is getting daffy.' When it worked they said, 'That was simple.' Engineers came from Russia to see one bridge built on top of another and the burning out of the old one. And we kept learning. On the Lake street bridge we let the 'L' trains through in

[23] R. F. Imler, "Wells Street Bridge Construction," in *Engineering World,* 20: 1–8 (January, 1922).

[24] Imler, in *Engineering World,* 20: 1–8.

Wabash Avenue Bridge, Chicago



Lafayette Avenue Bridge, Bay City, Michigan

three days, but it was weeks before we got the street level finished and paved. When we came to Wells street, a few years later, we had both levels open in seventy-two hours."[25]

Just as the Michigan Avenue bascule was an important unit in the now famous Chicago Plan, so the bridge crossing the railroad tracks at Roosevelt Road was a part of the vast project of straightening the Chicago River.[26] This work, too, was done while maintaining traffic on the street viaduct. At Roosevelt Road the new channel of the river — at the time of bridge-building not yet excavated — was west of the old channel, and the new bascule bridge cleared an old three-truss swing bridge. The removal of the old bridge was ordered by the war department in 1911, but because of the First World War and the city's plan for straightening the Chicago River, the swing bridge continued in service. It remained in use until the new channel was opened.

The new bridge — for the time being over dry land — was another double-leaf bascule. Measuring 204 feet center to center of the trunnion bearings, it was designed to give a clear span of 170 feet between masonry piers and a total width of 90 feet. Built in the late 1920's, it required clever engineering to overcome a number of serious problems, among them the need for heavy foundation work and the erection of steel under traffic.[27]

In July, 1929, the city completed a new bridge over the Chicago River at Clark Street. The sixth structure at this point, the bascule took the place of a swing bridge set up in 1888 — just before Pihlfeldt went to work for Chicago. The existing bridge, many times repaired, had witnessed the transition from man power to steam to electric motors. With the coming of motor-truck transportation and heavier streetcars, it had to make way for a modern bascule. It was particularly important to provide Clark Street with a structure adequate for modern needs, since as a streetcar thoroughfare it was surpassed only

[25] *Chicago Daily News,* October 15, 1936.

[26] See Thomas G. Pihlfeldt, "Straightening the Chicago River," in *Norwegian-American Technical Journal,* vol. 1, no. 4, p. 1–3, 8 (December, 1928).

[27] *Engineering News-Record,* 101:546–550 (October 11, 1928).

by Madison and State streets. With its completion the last of the old swing bridges was removed from the main branch of the Chicago River.[28]

Heavy increases in traffic over the Chicago River had caused the engineers in City Hall to think as early as 1922 of new facilities near Wabash Avenue. In 1927 final approval was given to plans for a bascule to be located on an angle from the center line of Wabash, and for a viaduct crossing the tracks of the Chicago and North Western Railway and connecting the north fixed approach of the bridge. Arrangements were made for streetcar tracks on both bridge and viaduct. Construction began late in 1929 and ended in October, 1930.

> Since the opening of this new thoroughfare, the Indiana avenue street car line, which formerly looped in the downtown district, now operates north on Wabash avenue over the new bridge to Grand avenue and east over Grand avenue to Navy Pier on the Lake front. The downtown district is now relieved of the looping-back of 36 cars of the Indiana avenue line which operate on a three-minute rush hour headway and a five-minute base schedule. Later, other routes will ultimately utilize the new bridge and relieve congestion in the business district.

The Wabash Avenue traffic artery will also serve as a link across the river to the planned North Bank Drive, which, when built, will resemble Wacker Drive on the south side.[29]

Mention will be made of only one more bascule bridge — a key structure in Chicago's Outer Drive, which links Chicago's south and north side lake-front boulevards and carries a vast traffic outside the crowded loop district. A conventional double-leaf bridge over the mouth of the Chicago River, its distinguishing feature is its great size and weight: 108 feet in width and 264 feet in length between trunnions, with leaves weighing 4,364 tons each. Provision was made for a future lower deck, and on the south side of the river a steel viaduct was designed as an approach to the bridge; another viaduct connects the bridge with Michigan Avenue at Randolph Street. On the north

[28] Paul Schioler, "Construction of the New Clark Street Bridge," in Western Society of Engineers, *Journal,* 34:629–634 (November, 1929).
[29] *Electric Traction,* 27:113–115 (March, 1931).

side a viaduct, supplemented by a 100-foot single-leaf bascule over the Michigan Canal, serves as an approach. This project, begun in 1929, was halted by the depression; it was resumed in 1935, and completed two years later.[30] The records do not reveal Pihlfeldt's part in designing and building this mammoth bridge. In all probability his was a consultative role; the leading spirit was Hugh E. Young, chief engineer of the Chicago Plan Commission.

Many problems, though seemingly of little significance, reveal the difficulties and at the same time the great interest that attach to bridgebuilding. The floor may be offered as an example. A number of paving materials had to be tested because of the tremendous volume of Chicago traffic.[31] When the Michigan Avenue bascule was twenty years old, it was given a new upper deck to replace the rubber-block paving which, in its day quite an innovation, had been laid fifteen years before. The new wearing surface was made of asphalt plank laid on timber sub-flooring. In the end zones, where excessive wear results from the stopping of heavy busses for traffic lights, a novel cast grid filled with concrete was used. The importance of such work is obvious when it is remembered that 50,000 vehicles passed over the Michigan Avenue Bridge each day in 1939.[32] The increase in traffic since then has been great.

The bascule is not the only type of bridge suited to problems in Chicago. A lift bridge was constructed over the Calumet River at Torrence Avenue, the principal traffic artery through the industrial area of south Chicago and the towns further south. The war department required a channel width of 200 feet, and the city had to reckon with the fact that the river is at a skew of about 50° with the street. A bascule bridge at this point would have required a clear span of 310 feet between masonry — nearly 80 feet more than the bridges at Wabash

[30] *Engineering News-Record,* 118:583–587 (April 22, 1937).

[31] See, for example, "Fibrated Asphalt Planking on La Salle Street Bridge, Chicago," in *Highway Engineer and Contractor,* 34:72–74 (May, 1929); and "La Salle Street Bridge, Chicago, Splendid Example of Modern Timber Floor Construction," in *Wood Preserving News,* 8:60–62 (May, 1930).

[32] *Engineering News-Record,* 123:626 (November 9, 1939).

and Wells streets. The cost of a bascule would therefore have been too great.

In view of these facts, a vertical lift bridge was found to be the most practicable solution. This type offers several advantages over the bascule type for a large span, because the ends can be skewed, as they are in this case, so as to reduce the actual span length, and the movable span is balanced by two counterweights, each equal to one-half the span weight, while in a bascule the counterweight arm weighs at least twice as much as the river arm. In the Torrence Avenue bridge, the span and its counterweights have a total weight of about 6,100,000 pounds, while the total movable load of a bascule bridge with 310 feet clear span would be at least 12,000,000 pounds, and the machinery to handle such mass and the wind loads thereon would become rather difficult.[33]

This first vertical lift bridge to be built in recent times in Chicago[34] gave Pihlfeldt unmistakable gratification. Both the design, with its novel features worked out under his direction, and the bridge's successful operation were proof that long concentration on bascule bridges had not lessened his skill in other directions. Not his least satisfaction came from the fact that, whereas the war department required that the bridge must open in 2 minutes, under ordinary conditions it actually opened in 94 seconds.[35]

Pihlfeldt, as bridge engineer of Chicago from 1901 until his death in January, 1941, lived through the entire period of the development of the Chicago bascule bridge. During this time 35 movable structures were designed by the bridge division. In addition, Pihlfeldt supervised the building of about 20 fixed bridges and viaducts — an impressive total of 55 bridges! He was chosen in 1918 to represent Chicago during the construction of the Union Station. He also played an important part in the execution of the Chicago Plan — worked out by D. H. Burnham — and the straightening of the Chicago River, begun in 1928. His reputation, however, will rest on his work with the bascule bridge. As the city engineer, Loran D. Gayton, said at the time of Pihlfeldt's death:

[33] *Norwegian-American Technical Journal,* vol. 11, no. 1, p. 1 (February, 1938).
[34] *Engineering News-Record,* 121:618–622 (November 17, 1938).
[35] *Skandinaven,* January 14, 1938.

> While the fundamental principle of bascule bridges is centuries old, the application thereof to modern bridge structures, capable of successfully serving the needs of a metropolitan area, involves the application of engineering science and ingenuity requiring the greatest skill. It was in this application and the stage of perfection to which it has been carried in the modern bascule bridge which made Mr. Pihlfeldt a master in his field. The adoption of many of these developments by various engineers throughout this and other countries is the finest testimony to his high standing in his profession.[36]

Pihlfeldt's appraisal had been similar.

Skandinaven, in a short article of January 27, 1938, refers to Pihlfeldt as the inventor of the bascule, or, as the paper calls it, the Pihlfeldt type of bridge. Such an assumption, however common even among the non-Norwegian element in Chicago, was entirely without foundation and not at all pleasing to Pihlfeldt himself. Asked by a reporter if he were the inventor of the bridge, Pihlfeldt answered with as much truth as modesty that it had developed down through the centuries. "It is just two teeter-totters," he said, "one set on each bank of a river with machinery to lift the ends that touch when a boat whistles to go through. . . . I invent the bascule? Why Cain and Abel played on a bascule." He continued:

> When we of the bridge division decided shortly after the turn of the century that the traditional swing bridges set on a turntable in the middle of the river were too slow to operate and too costly to maintain, we studied all of the bridges in the cities of Europe and America. The best we found to copy was the bascule in the London Tower bridge.
>
> The first one built here was in Cortland street. We have designed and constructed forty-nine river bridges in Chicago and maintain them in daily operation. I say we because I could do nothing without the loyal and efficient staff of 100 men in the division, engineers, draftsmen, mechanics, electricians and operators and without the readiness of city engineers and commissioners above me to accept new ideas.
>
> All that I claim credit for is being constantly on the alert, traveling around the country when need be, to watch every improvement in bridge building in every city and apply that new thing, bettering it, usually, on the next bridge built by the city of Chicago.[37]

[36] "Thomas George Pihlfeldt, 1858–1941," in Municipal Employes Society, *Monthly Bulletin*, 21:17 (February, 1941).

[37] Dan Fogle, in *Chicago Daily News*, October 15, 1936.

The result of the efforts of Pihlfeldt and other Chicago engineers was, nevertheless, that Chicago came commonly to be regarded as the birthplace and home of the modern bascule. There it reached its highest perfection and became a model for engineers both at home and abroad.

III

The Chicago River is little more than a good-sized creek with low-lying banks. It is completely tamed by man; its course has been changed until now it actually runs in a direction opposite from the one intended by nature, flowing lazily through the concentrated Chicago loop district into the drainage canal and the Illinois and Mississippi rivers. The Mississippi, by contrast, is a mighty river rightly called the Father of Waters, and along its entire north-south course, bridge engineers have brought forth their best efforts in overcoming one of the main obstacles to east-west transportation. Both railroad and highway traffic over the Mississippi have demanded of the bridge-builder that he keep pace with the finest in the building art and at times that he proceed without benefit of precedent.

At the head of navigation on the Mississippi lie the Twin Cities of Minnesota — St. Paul and Minneapolis — with a combined population of about three-quarters of a million. St. Paul developed very early into an important commercial center engaging in steamboat and overland trade, and Minneapolis, settled somewhat later, has grown into an industrial city — once a home of lumber mills, now a flour-milling center. Together the two cities are an important market for farm products, especially wheat and livestock, and they in turn supply a vast northwest area with finished goods for town and country. Located in the middle of an area rich in natural resources, the Twin Cities also constitute a natural financial and cultural center.

The Mississippi, which loops its way through the Twin Cities, now divides Minneapolis into a large western part and a considerably smaller eastern division, and at the Falls of St. Anthony provides the power needed for a cluster of flour mills.

A system of locks and dams, begun in 1915, makes the Mississippi navigable to the heart of the city. The greater part of St. Paul is on the north bank of the river and rises to three levels, the first being occupied by railroad yards and industry, the second by the business section, and the third by residences. The city enjoys a fine harbor and has the greatest inland river terminals on the Mississippi above New Orleans.

When the people who founded St. Paul seized upon the good boat landings at the foot of Sibley and Eagle streets, they discovered that just to the north was land available for a townsite. In the early 1860's the first train chugged into the settlement and a station was built opposite Wacouta Street. Thus the picturesque site of the future business district was fixed. Surrounding the rapidly growing settlement both to the south and east were the river and high sandstone bluffs. Deep ravines also followed Phalen Creek and Trout Brook.[38] Over in Minneapolis the first dwelling house was reputedly built at St. Anthony Falls in 1848, and two years later the first was erected in Minneapolis proper. Between the towns of St. Anthony and Minneapolis, which were united in 1872, early communication was by ferry in the summer and on ice in the winter. It was there that the first bridge was built.[39]

Since the two cities have one obstacle in common — the Mississippi, running from the northern boundary of Minneapolis to the southern boundary of St. Paul — bridges both within and between the two cities were obviously imperative as a normal part of their development. At first, because of the ready supply of materials from the sawmills at St. Anthony, the bridges were built chiefly of wood, but later wrought iron, steel, and reinforced concrete came into popular use. Certain other facts conditioned the Twin City bridgebuilding program. The coming of the automobile and the truck and the converging of many highways into the cities placed a heavy burden on the bridges,

[38] M. S. Grytbak, "St. Paul Bridges Fifty Years Ago," in Minnesota Federation of Architectural and Engineering Societies, *Bulletin*, 18:17 (October, 1933).

[39] F. W. Cappelen, "The Late Suspension Bridge of Minneapolis," in Association of Engineering Societies, *Journal*, 10:400 (August, 1891).

and called for designs recognizing greater concentrated loadings than were needed for teams and carriages. The fact that many of the highway bridges also carry streetcar tracks demanded sturdy construction as well as adequate width for the two-way traffic of streetcars, motor vehicles, and pedestrians. Alternating spells of freezing and thawing in the Minnesota spring and fall made it necessary that careful precautions in waterproofing be taken. Since two major bridges — the Ford and the Marshall Avenue-Lake Street bridges — served both St. Paul and Minneapolis, yet another element had to be introduced — joint planning and financing. And, finally, the scenic beauty of the Mississippi is such that pleasing design and suitable building materials were required in an unusual degree. In the words of the city engineer of St. Paul, "Nature has perhaps nowhere provided a more beautiful setting for an arch bridge than in the Mississippi River valley between Fort Snelling and St. Anthony Falls."[40]

The Twin City area has a heavy Scandinavian population. It is therefore not surprising that many Norwegian engineers should have been attracted to this metropolitan center, which after the dull 1870's experienced a rapid growth. They were employed both by the many railroads that serve the Northwest and by the engineering departments of the two cities. Four Norwegian engineers played major roles as builders of bridges in the Twin Cities; many others had minor but significant parts. The chief figures, in the order of their appearance on the scene, were Kristoffer (Kris) Oustad, Andreas W. Münster, F. W. Cappelen, and M. S. Grytbak.

Kristoffer Olsen Oustad came to America by way of Trondhjem's Technical College in 1882. He entered the Minneapolis city engineer's office in 1883 and remained forty-six years. He went through the customary stages of draftsman, estimator, and assistant engineer, and, in 1893, became municipal bridge engineer. During his long service, ended by retirement in 1929,

[40] George N. Shepard, "Twin City Bridge Construction," in *Minnesota Techno-Log*, 7: 137 (February, 1927).

he had general supervision of the Minneapolis bridges for both design and construction. His career was distinguished by careful planning and sound engineering ability.[41]

Whereas Oustad came from a farm of southeastern Norway and represents the sturdy *bonde* element of Hedemark, Andreas Wendelbo Münster was born at Bergen, the son of a well-known military figure and of a sister of Ole Bull, the violinist. Münster received his technical training at the popular Chalmers Institute in Gothenburg, Sweden. Arriving in the United States in 1883, he set out for the West and, after varied experiences in railroad construction and surveying, became bridge engineer for the city of St. Paul in 1884. Twenty years later he left St. Paul to become chief engineer of the Chicago, Great Western Railway and in 1906 he moved to Seattle, where he opened an office as consulting engineer. His reputation had preceded him and he found, as a result, that his services were widely sought. Consultant for the Chicago, Milwaukee, and St. Paul Railroad Company during the construction of its western extension to Seattle, he also designed several railroad terminals and division structures in Idaho and Washington—including docks, wharves, and freight houses. In Tacoma, Seattle, and Vancouver he did important work for the Great Northern Railway Company, and in addition served as consulting engineer for the city of Seattle, returning once more to bridge designing. From 1923 to 1929 he served as chief engineer of the city's bridge department and at the time of his death, in 1929, was regarded as one of the best bridge engineers of his generation.[42]

Frederick William Cappelen, one of the great American engineers, was educated in the technical school at Örebro, Sweden, and at the Polytechnicum in Dresden, Germany. He was graduated from the latter school with the highest record ever attained by a foreign student. Cappelen set out for the New

[41] *Norwegian-American Technical Journal,* vol. 2, no. 3, p. 10 (November, 1929); Alstad, *Trondhjemsteknikernes matrikel,* 31; Alstad, *Tillegg,* 18; *Skandinaven,* September 11, 1936; interview with Oustad, March, 1940.

[42] American Society of Civil Engineers, *Transactions,* 95:1565 (1931); *Nordmandsforbundet,* 22:282 (1929); *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 5 (July, 1929).

World in 1880, to find employment, like so many others, with the Northern Pacific Railway. His municipal career began in 1886, when he became bridge engineer of Minneapolis. He was elected city engineer in 1893—and re-elected in 1913. From 1898 to 1913, the period between terms of office, he was a consulting engineer in municipal and bridgework. By no means recognized only for his bridge designs, he planned the Mississippi reservoir system, which was the first step toward the purification of Minneapolis' water supply. This and his later participation in other improvements resulted in his being called by some the father of the city's present waterworks system. In 1904 he served on a commission with Andrew Rinker, then city engineer, and Allan Hazen of New York City, which studied the problem of a pure water supply. The commission's report favored the purification of Mississippi River water. The operation of the city's filtration plant was begun under Cappelen's direction in 1913, and by 1921 its capacity had been increased to 90,000,000 gallons per day.

During 1907–11 Cappelen was also associated with the Decaries Incinerator Company, and he devised a number of improvements in the garbage reduction process. In still another field he was a pioneer; his extensive studies of grade separations at street and railroad crossings led to considerable improvement in this field and to the outlining of plans for future work. Cappelen's reputation as a sanitary engineer caused the governor of Minnesota in 1918 to name him one of the first two engineers to be members of the state board of health, a position to which he was reappointed shortly before his death. Brilliant, original, daring, Cappelen was an eminently sound engineer who did much for transportation, the public health, and safety in Minneapolis, as well as for the natural beauty of the city.[43]

The fourth engineer to figure in the story of Twin City bridgebuilding is Martin Sigvart Grytbak. He attended Trond-

[43] American Society of Civil Engineers, *Transactions*, 85:1663 (1922); *Norwegian-American Technical Journal*, vol. 2, no. 3, p. 9 (November, 1929); *Skandinaven*, September 11, 1936; *Nordmands-forbundet*, 6:204 (March, 1913); and archives of Norwegian-American Technical Society, Chicago.

hjem's Technical College, was graduated as a civil engineer in 1903, and left for America two years later. Grytbak, who had relatives in Minnesota, went to the Twin Cities, where he too became a draftsman with the Northern Pacific Railway in St. Paul. He worked in the bridge department and was promoted to chief draftsman eight years later. In 1913 he resigned to become bridge engineer for St. Paul. This position, which calls for almost exclusive concentration on bridges, he still occupies very efficiently.[44]

Though best known as a builder of tunnels, Olaf Hoff also had a distinguished career as bridgebuilder. Shortly after his arrival in America, Hoff entered the service of the Keystone Bridge Company in Pittsburgh and soon rose to the position of assistant chief engineer. During 1881–83 he was bridge and locating engineer on the Tampico division of the Mexican Central Railway. He then returned to Pittsburgh to become chief engineer of the Schiffler Bridge Company. From 1885 to 1901, while maintaining a consulting and contracting practice in Minneapolis, Hoff was also western representative of the Schiffler Bridge Company and engaged in considerable bridgework, in both the designing and consulting phases. In addition to his work in the Twin Cities, he designed a highway bridge across the Mississippi at Muscatine, Iowa, that was 2,000 feet long and had a 400-foot cantilever span. He also made competitive designs for bridges both in the East and in the West.[45]

IV

There have been two decades of feverish bridgebuilding in the Twin Cities — the 1880's and the 1920's. Both periods were characterized by general prosperity. The first bridges, it is true, were built before the Civil War; a suspension bridge at St. Anthony Falls was erected during the winter of 1854–55, and the

[44] Alstad, *Trondhjemsteknikernes matrikel,* 198; Alstad, *Tillegg,* 55; *Norwegian-American Technical Journal,* vol. 1, no. 4, p. 11 (December, 1928); interview with Grytbak, April, 1940; and letters from Grytbak to the present writer.

[45] American Society of Civil Engineers, *Transactions,* 89:1623 (1926). It is interesting that Hoff, when employed by the New York Central and Hudson River Railroad, renewed or reconstructed some 400 bridges; *Harper's Weekly,* 56:22 (March 23, 1912).

Wabasha Street Bridge in St. Paul was built in 1857–58. Their completion, however, was followed by a long lull, during which the Civil War and the difficult times that followed, especially after 1873, put a damper on expensive projects. By the early eighties a pronounced change had taken place, and bridges, both railroad and highway, leaped across the river at numerous strategic points. After the 1880's this nervous tempo subsided considerably, only to revive again during the prosperous 1920's. Though spanning the mighty Mississippi brought lasting benefits to the area, at least one large project, begun during the eighties, was never completed. This was the St. Paul Broadway Bridge; an abutment at the north end of State Street is a historic record of the optimism of an earlier day.[46]

The highway bridge at the foot of Wabasha Street was first built by a private company before the Civil War and was operated on a toll basis. Known as the St. Paul Bridge, and built throughout of timber, it was reconstructed of iron in the 1870's. With the rapid increase of traffic in the next decade, the bridge proved too light for its added burden; the channel span, in particular, was found to be in poor condition. In 1889 the northern section, measuring 600 feet, was replaced under Münster's direction with a new cantilever structure having a 36-foot roadway and 10-foot sidewalks. In 1900 the south portion was rebuilt to the same width as the northern, and the bridge was shortened about 300 feet by an embankment at the south end. During construction the old spans were moved to one side and supported on temporary piers. About 700 feet of makeshift bridge had to be built over the south arm of the river to carry traffic for a year while work was going on. This engineering feat was accomplished without a single hitch.[47]

The first Minneapolis bridge designed by a Norwegian en-

[46] *Minnesota Techno-Log,* 7:137 (February, 1927); and Minnesota Federation of Architectural and Engineering Societies, *Bulletin,* 18:18 (October, 1933).

[47] *Engineering Record,* 25:58 (December 26, 1891); F. B. Maltby, "Historical and Descriptive Sketch of the Bridges over the Mississippi River," in Western Society of Engineers, *Journal,* 8:434–437 (1903); A. W. Münster, "Temporary Bridge across the Mississippi River, at St. Paul, Minnesota, Moving of Three 140-Foot Spans," in Association of Engineering Societies, *Journal,* 24:58–61 (January, 1900).

gineer was perhaps the Northern Pacific Railway bridge, about one mile below St. Anthony Falls and a short distance above Washington Avenue. It was constructed in 1884–85 and rebuilt before the First World War. A double-track deck bridge, it had two spans and a viaduct and carried trains about 100 feet above the water. Cappelen designed it, and it was one of the first steel bridges in the Northwest.[48]

The old Robert Street highway bridge in St. Paul was built by Münster, in 1885–86, just downstream from the Chicago, St. Paul, and Kansas City Railway bridge. Built of iron, the bridge consisted of several pin-connected spans totaling about 1,540 feet in length. The channel section was a through span of 350 feet. It had fourteen pedestal masonry piers and six river piers.[49] Though it was in fair condition, this bridge had to be replaced in the middle 1920's because its roadway was only 33 feet wide, yet carried a double-track streetcar line in addition to two 10-foot sidewalks.[50]

Other Münster structures include the Sixth Street viaduct, built in 1887, and the Colorado Street skew stone and brick arch, built in 1888. Speaking of the fine masonry construction of the eighties, Grytbak said of the design and cutting of the outside ring stones of the Colorado structure, that it "is now an art of the past." This was also true of the piers of the old Robert Street Bridge.[51]

During 1888–89 St. Paul built what was to be known as the High Bridge at Smith Avenue. This wrought-iron crossing reached from the bluffs on the St. Paul side to those on the right bank of the Mississippi and connected the business center of a rapidly growing city with what at that time was a beautiful residential district. It also opened direct lines of communication with the rich agricultural region of Dakota County. This bridge has a maximum height of 200 feet above water level and is

[48] Maltby, in Western Society of Engineers, *Journal,* 8:425–427.

[49] Maltby, in Western Society of Engineers, *Journal,* 8:437.

[50] Walter H. Wheeler, "Minnesota Bridge Construction," in *Minnesota Techno-Log,* 6:160 (February, 1926).

[51] Minnesota Federation of Architectural and Engineering Societies, *Bulletin,* 18:18 (October, 1933).

some 2,774 feet in length. Designed as a series of bents and towers with long and short deck spans, it crosses the river with four 250-foot spans resting on high steel towers and rocker bents. The plans were prepared in the bridge division under Münster. The foundation consists of masonry piers on timber grillage and piling. The bridge is unusual because of the lightness of its construction, as well as its great height. The structure was partially destroyed by a cyclone in August, 1904, but it was quickly restored and serves to this day as a highway bridge.[52]

Meanwhile in Minneapolis a great deal of interest had been shown in that city's much overrated suspension bridge and in Cappelen's construction of the Steel Arch on Hennepin Avenue. The story goes back to what is believed to be the first bridge over the Mississippi, a cable suspension opened to the public in January, 1855, and operated on a toll basis.[53] Just above St. Anthony Falls, it connected the west bank of the Mississippi with Nicollet Island and was expected to draw the trade of settlers on the west side. With the growth of trade and manufacturing in the area once occupied by farmers, a light toll bridge with a span of 675 feet took the place of the original structure in 1876–77. Soon the sidewalks of the new suspension bridge had to be widened and steps were taken to get additional bridge facilities next to and paralleling the suspension bridge. In 1888 the first half of a steel arch was built, upstream, within a few inches of the old structure. But this arrangement was unsatisfactory: the suspension bridge was constantly in need of repair. According to Cappelen there was "always something wrong; an eye breaking here and a bolt there, and the trusses always loose and rickety. When the beams were spliced to widen the sidewalks I am told there were strong indications of

[52] *Minnesota Techno-Log,* 7:160 (February, 1927); *Engineering and Building Record,* 19:144, 158, 175, 242, 313–315 (February 16, 23, March 2, April 6, May 11, 1889), 20:102 (July 20, 1889), and 21:38, 56 (December 21, 28, 1889); and American Society of Civil Engineers, *Proceedings,* 30:794–799 (1904) and 31:160–168 (1905).

[53] Cappelen has given us the toll charges on the first suspension bridge: for each foot passenger, 5 cents; for horse or mule, with or without driver, 15 cents; for two-horse, two-mule, or two-ox team, with or without driver, 25 cents; for single-horse carriage, 25 cents; for sheep or swine, 2 cents; and so on.

beams rotting." A thorough investigation revealed that the structure was entirely bad, and the bridge was therefore closed. The question of whether to repair the suspension or to tear it down and complete the steel arch naturally passed from the city council to the newspapers, which despaired at the prospect of losing the beloved suspension. After attempts had been made at repair, however, the suspension was taken down and the Steel Arch, designed by Cappelen and Andrew Rinker (the city engineer) was completed. The new structure, built between 1888 and 1890, consists of two steel arch spans of adequate width.[54]

Mention should be made, too, of a Minneapolis railroad bridge built by Olaf Hoff for the Minneapolis and Western Railway in 1891. This bridge is located a short distance below Tenth Avenue and is now used by the Great Northern Railway Company. It is a deck structure consisting of several channel spans and a long, heavy viaduct. The two river spans were built with a single, heavy, two-post rocker trestle bent supporting their fixed ends, and four-post iron towers supporting their opposite ends. They were erected without the use of falsework.[55]

The decade that followed the active 1880's was a surprisingly quiet one. The only notable municipal undertaking was the widening of the Stone Arch over the east channel of the Mississippi in Minneapolis, to make provision for the increased volume of traffic over this beautiful old highway bridge. Because the structure was still in good condition, it was decided in 1895 to enlarge and continue to use it. Cappelen, now city engineer, worked out the unusual plans which permitted a doubling of width and traffic capacity at a surprisingly low cost. The 40-foot-wide stone arches could not easily be enlarged and new arches would have been equivalent to a new bridge. Therefore,

[54] Thomas M. Griffith, "The Minneapolis Suspension Bridge," in *Van Nostrand's Eclectic Engineering Magazine,* 18:248–251 (March, 1878); F. W. Cappelen, "The Late Suspension Bridge of Minneapolis," in Association of Engineering Societies, *Journal,* 10:400–426 (August, 1891); *Engineering and Building Record,* 21:358 (May 10, 1890); *Minnesota Techno-Log,* 7:138 (February, 1927).

[55] *Engineering Record,* 29:37 (December 16, 1893).

Cappelen devised a steel platform on each side of the bridge, thus widening the roadway about 40 per cent and adding sidewalks without greatly disturbing the old masonry or requiring additional piers. According to the *Engineering Record*, the construction that made this possible was "novel and ingenious, and secures a rigid and economical support for the main girders."[56]

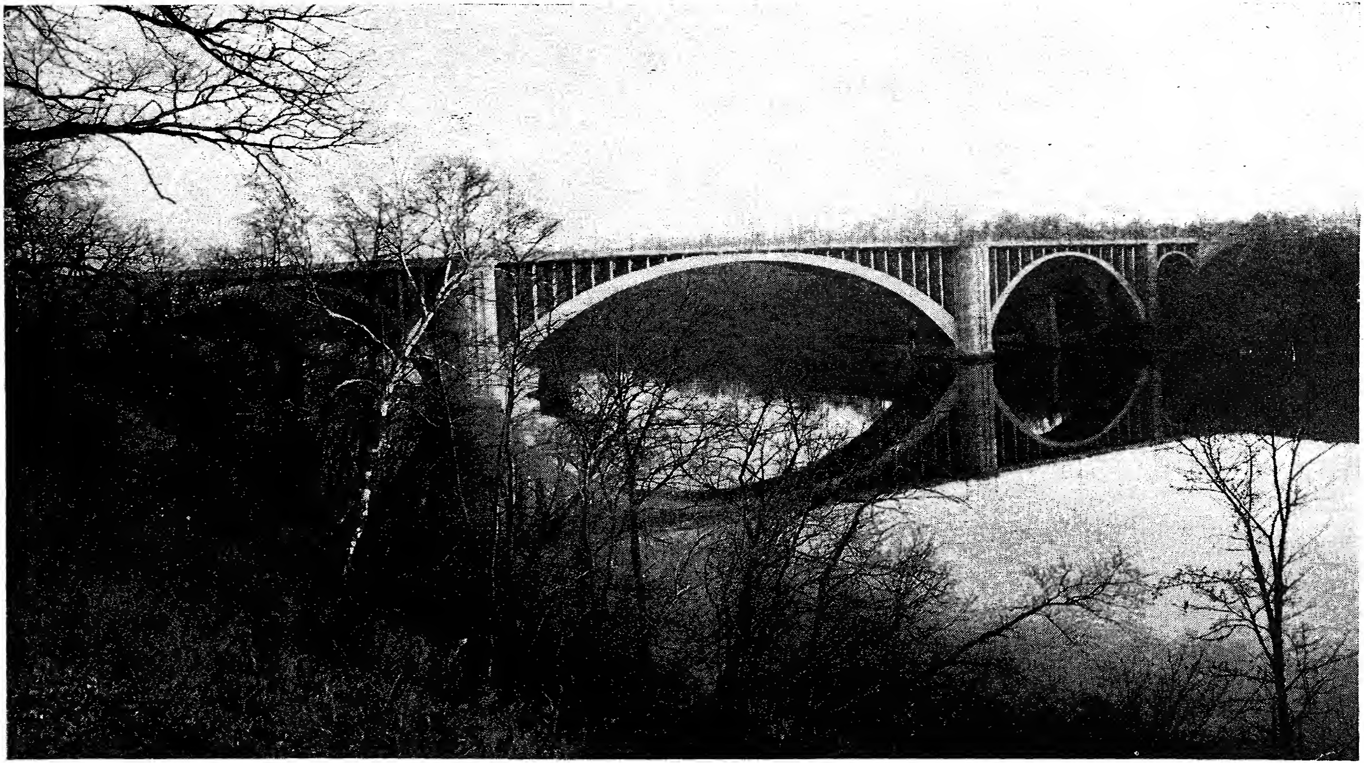
The first of the graceful reinforced-concrete arch bridges in the Twin Cities was built during the First World War in the neighborhood of Third Avenue in Minneapolis. There had been for some time, as a natural consequence of the city's growth, a demand for a handsome crossing at this point. In 1912 the city council responded to public pressure and asked the Concrete-Steel Engineering Company of New York to prepare designs for a concrete arch bridge between Third Avenue South and First Avenue Southeast. The resulting designs were subjected to a public hearing before the engineers of the war department in 1913. At this point the water-power companies, which had strongly opposed a bridge, announced that, if necessary, they would go to the courts to fight any bridge project so near the falls.[57]

The reason for this opposition also explains the design of the bridge that ultimately resulted. The river bottom at Third Avenue consists of a limestone bed about 15 feet thick; this is almost bare in the west channel and covered only by sand and silt in the east channel. The limestone ledge rests in turn on St. Peter sandstone, which goes down about 600 feet. When the power at St. Anthony Falls was first utilized, it was found advantageous to dig tailrace tunnels in the soft sandrock below the limestone.[58] These tunnels broke through at two points, causing the federal government to make repairs that closed the breaks and thereby also insured continued water power. The sinking of bridge foundations might easily have undone the ex-

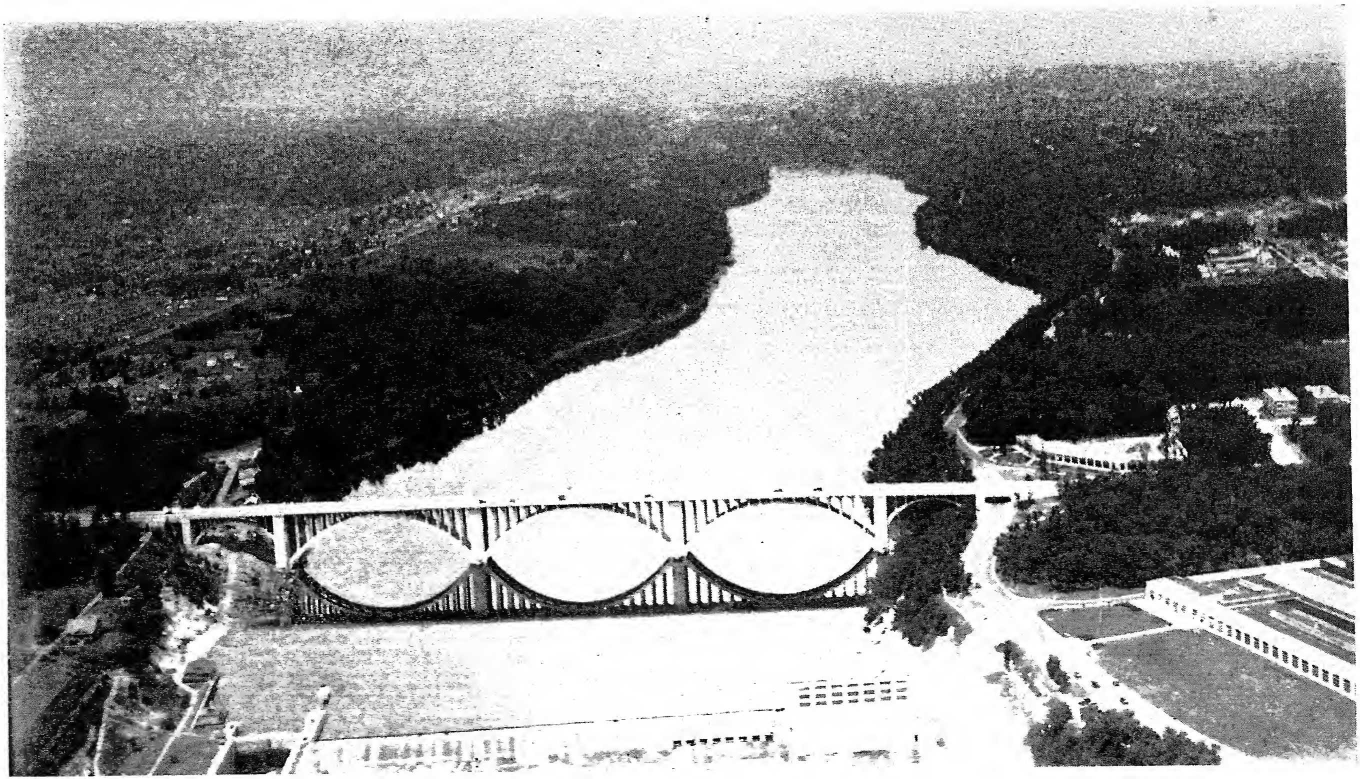
[56] Vol. 32, p. 454 (November 23, 1895).

[57] A. M. Richter, "A 2,223-Ft. Concrete-Arch Bridge Built on Reverse Curve," in *Engineering News*, 74:1268–1273 (December 30, 1915).

[58] "The water was led from the mill pond in a canal above the limestone, and the tunnels served as tailraces"; Richter, in *Engineering News*, 74: 1268.



Cappelen Memorial (Franklin Avenue) Bridge, Minneapolis



Intercity (Ford) Bridge, Twin Cities

tensive repairs, which had restored the condition of the river bottom almost to normal. Hence the opposition of the power companies and the use of curved ends for the bridge when it was finally built.[59]

While the power interests were fighting the plans drawn up by the New York firm, Cappelen was elected city engineer in Minneapolis. His experience as bridge engineer had given him the knowledge necessary to cope with the situation. Refusing to approve the location that had been selected, he influenced the council to reject these plans and to approve a steel bridge that would not endanger the falls or in any way affect power rights. Considerable opposition developed to Cappelen's proposed steel bridge, which would have had one span clearing the whole area of limestone breaks. The opposition sprang chiefly from aesthetic considerations. "At this time, however, Mr. Cappelen conceived the idea that by adopting a curved location for the line of the bridge, a design satisfactory to all parties might be worked out. On investigation it was found that at one point the limestone break could be cleared by a concrete arch of 211-ft.-clear span. A revised plan for the desired ornamental structure was then prepared. This proved satisfactory to all parties and was finally adopted."

The problem thus solved, Cappelen and Oustad exercised real skill in constructing the reinforced-concrete bridge now spanning the river. Consisting of seven main river spans, the bridge is 2,223 feet long and has a wide roadway that carries a double-track street railway and sidewalks. Its peculiar feature, however, is its gracefully curving design.[60]

Bridges must at times be protected against the elements. A serious problem arose when the Marshall Avenue-Lake Street Bridge threatened to become partly submerged; a government dam had raised the water some 30 feet for a distance of about 6 miles up to the falls. Most of the bridges, supported as they

[59] Richter, in *Engineering News,* 74:1269. See also *Minnesota Techno-Log,* 7:162 (February, 1927), and Chas. F. Bornefeld, "Design and Construction of the Third Avenue, South, Concrete-Steel Arch Bridge, Minneapolis, Minn.," in *Municipal Engineering,* 53:242 (December, 1917).

[60] Richter, in *Engineering News,* 74:1269, 1270–1273.

are on high masonry piers, were not affected, but the dam raised the water over the tops of the piers at Marshall Avenue and threatened to submerge about 5 feet of the ends of the steel arches. Concrete protecting walls were built under Grytbak's direction around the north abutment and the center pier of the bridge to a point 1 foot above high water. The steel was cleaned by sandblast and blowtorch and painted with mineral pipe coating applied hot.[61]

Though the twenties saw the first of the beautiful million-dollar bridges across the Mississippi, the Cappelen Memorial Bridge at Franklin Avenue was actually begun in 1919 and only completed in 1923. What made this bridge famous and brought engineers from Europe to study it was neither its simple and rugged beauty nor its cost, but the fact that in its 400-foot center span it had the longest concrete arch until then ever built. The Cappelen Bridge, 1,100 feet in length, is located in Minneapolis' southwestern residential district; Franklin Avenue, which crosses it, is a main link between two well-settled city districts formerly served by a thirty-year-old five-span steel bridge. The need for a new crossing at this point was so great that Cappelen, after the completion of the Third Avenue Bridge, immediately put his mind to the problem; it was he who made the general plans, though he did not live to see them completed. Oustad was immediately responsible for the design of the structure that was to become a memorial to Cappelen's long municipal service.[62]

Permanence and beauty were especially desirable in the Franklin Avenue Bridge — the latter because of the scenic surroundings. The only building materials that would give the desired monumental appearance were stone and concrete. Of the two, concrete reinforced with steel was the more practical. An arch bridge was best from an aesthetic point of view, but

[61] *Engineering and Contracting,* 48:538 (December 26, 1917), and *Engineering News-Record,* 79:1195 (December 27, 1917).

[62] Some of the best discussions of this bridge are *Engineering News-Record,* 90:148–152 (January 25, 1923); *Concrete,* 24:207 (May, 1924); *Cement and Engineering News,* 32:21 (May, 1920); *Minnesota Techno-Log,* 6:145 (February, 1926), and 7:174 (March, 1927).

navigation requirements called for a span at least 300 feet long and a clearance height of 50 feet—presenting a real problem to the engineer. Where Franklin Avenue crosses the Mississippi the distance between the gorge's limestone bluffs is over 1,000 feet. Ponding, resulting from the government dam several miles downstream, caused some people to believe that river navigation would become important in the future; for the present it necessitated special precautions against high water. It was also desirable that construction of the new bridge interfere as little as possible with traffic across the old one—that at least a crossing for pedestrians should be maintained during construction. Since there was also a possibility of using the old bridge for the transportation of materials used in construction, it was decided to build over and around that structure and to thrust the main span long enough to pass beyond the old piers.

The sides of the gorge naturally invited the larger part of the thrust of the 400-foot span, and to transmit the thrust, it was desirable to make the approach spans as long as possible; unfortunately, however, the nature of the gorge limited the length of the latter to about 200 feet.

> Under these conditions the thrust on the main piers could not be balanced, unless the side arches had been made of shallow rise by depressing the crown far below roadway level, which was not considered esthetically desirable. But a pleasing proportioning of spans was obtained, and Mr. Cappelen's skill and good taste in design soon developed this layout into the general plan as now being carried out. . . .
>
> The detailed design, largely worked out by Mr. Oustad, is unusually simple in its architectural features, making use of almost no ornament; for example, the ends of the spandrel columns are simple square faces, without any molding. The result is a demonstration of what can be achieved with plain details provided the structural proportioning is good.[63]

In June, 1927, the Intercity (or Ford) Bridge was completed, connecting the Highland-Ford Parkway in St. Paul with Forty-sixth Avenue South and Minnehaha Park in Minneapolis. Another reinforced-concrete arch bridge, it consists of a main

[63] *Engineering News-Record,* 90:149.

structure of 1,520 feet spanning the river and 1,200 feet of approaches, including an overhead viaduct and an undercrossing bridge for the separation of grades. A state law specified that the new bridge was to be constructed by a Twin City committee with C. M. Babcock, state highway commissioner, as chairman. The design and construction were worked out under the general direction of the city engineers of Minneapolis and St. Paul. Grytbak was in immediate charge of the preparation of plans and was later entrusted with construction, which began in August, 1925.[64]

Where the Intercity Bridge crosses the Mississippi, a short distance above the high dam, the river has a deep narrow gorge in the sandstone, filled to a depth of 35 feet with sand, gravel, and boulders; the water is also about 35 feet deep and about 1,000 feet in width. To cross the gorge, three main arches were provided with 300 feet of clear span, each with two-arch ribs having a rise of about 88 feet. These were flanked on either end by an arch of about 139 feet. The concrete viaduct has four shorter arch spans at right angles to the bridge; thus riverfront pleasure drivers ride under the bridge approach on the east side. The roadway of the bridge proper was designed for heavier traffic than the Cappelen Bridge and provides a double streetcar track.

The Intercity Bridge differed from the Cappelen in its foundation problem. The sinking of the pier caissons and the construction of sheet pile cofferdams in deep water constituted a most difficult feature. According to the city engineer of St. Paul, George M. Shepard, the piers were "carried down to solid rock a depth of 70 feet below water level." He continues:

> With practically 35 feet of water above the gravel, coffer dam construction was extremely difficult. It was, however, successfully carried out by driving single sheet steel sheet piling 50 feet long

[64] For the Intercity Bridge, see P. Caufourier, "Pont en béton armé sur le Mississippi entre Saint-Paul et Minneapolis (Etats-Unis)," in *Le Génie Civil*, 93:236–238 (September 8, 1928); M. S. Grytbak, "Concrete Arch Bridge over the Mississippi," in *Engineering News-Record*, 99:754–758 (November 10, 1927); Minnesota Federation of Architectural and Engineering Societies, *Bulletin*, 13:21–28 (July, 1928); and *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 1, 14 (March, 1929).

about each of the two center piers. Forms for the four concrete caissons of 10 feet inside diameter were located in their proper position inside the coffer dam of each pier. The caisson shell was concreted in this position and the cylinders sunk to rock without accident or failure. . . . Following the sinking of the cylinders the interiors were filled with concrete and a 10 foot slab of concrete poured about the tops for the entire area of the pier. The water was then pumped from the coffer dam and the pier construction carried above water line.[65]

Another unusual feature of this project was the cableway, supported by movable towers, which carried form materials, sheet piling, and concrete out over the river to where it was used. This, combined with the concrete plant on the Minneapolis side — one of the best in the Northwest — made for an ingenious working arrangement that was well described in an account written at the time of building:

Materials are dumped from trucks into chutes at the top of the cliff and go by gravity flow directly into bins above the mixing drums. The mix is proportioned by weight in a hopper resting on the lever system of a large dial scale. From the drums, the mixed concrete is transported up by belt conveyor to the cableway bucket loading platform at the top of the bluff. It takes four minutes for the mix to be transported from the mixing drums to the forms in the bed of the river.

The entire works are run with electric power supplied from two generators driven by Diesel engines.[66]

The civil engineer not infrequently has had to contend with the politician, whom he unjustly despises, and a type of architect-aesthete, whose fine sensibilities are often disturbed by the vigorous honesty of engineering designs. Both politicians and aesthetic architects had their innings during the building of the Intercity Bridge, as in all such projects, and no one was more keenly affected than Grytbak.

Certain factions in St. Paul were anxious to postpone the project indefinitely, and for a while had the newspapers and a number of

[65] *Minnesota Techno-Log,* 7:192 (March, 1927).

[66] Walter H. Wheeler, "Minnesota Bridge Construction," in *Minnesota Techno-Log,* 6:160 (February, 1926). See also Charles R. Hansen, "Methods of Concrete Control and Some Test Results in the Construction of a Concrete Arch Bridge across the Mississippi River between St. Paul and Minneapolis, Minnesota," in Minnesota Federation of Architectural and Engineering Societies, *Bulletin,* 13:21–28 (July, 1928).

city organizations attacking the committee and engineers which had the bridge in charge, and the architects especially were incensed over not having been consulted in the design of the structure. The plans when completed were severely criticized by the architects; especially were the 139-foot approach arches the point of attack. The selection of these spans was made by the engineers for reasons of economy because the preliminary plans and estimates had shown a two-hundred-thousand-dollar increase in the cost were each 139-foot span to be replaced by three short-arch spans. While the shorter spans would have added to the massiveness of the approaches, the hazards of construction would have been larger, and the cost would have exceeded the $1,600,000 bond issue. This at least would have delayed the project for another two years. Since the completion of the bridge, no further criticism has been heard; in fact, the committee has received compliments for its appearance as well as the workmanship.[67]

The fourth of the Twin Cities arched concrete bridges in whose design and construction a Norwegian engineer took part crosses the Mississippi at Cedar Avenue in Minneapolis.[68] This bridge was completed in September, 1929, at a cost of about $1,260,000, a figure somewhat greater than that for the Cappelen bridge. It was the opinion of Oustad and also of other engineers that in designing the Franklin Avenue structure he had made it too heavy; the Cedar Avenue Bridge is consequently lighter in plan, with smaller arch spans and concrete bents.[69] Two 250-foot spans form the channel portion of the structure; their crown rises about 110 feet above low water. Like the Third Avenue Bridge, this one is built on curves, the reason for this arrangement, however, being the nature of

[67] M. S. Grytbak, "Concrete Arch Bridge over the Mississippi River between St. Paul and Minneapolis," in *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 14 (March, 1929).

[68] It should perhaps be noted that Oustad, in Minneapolis, designed the bridges across Minnehaha Creek, Bassett's Creek, and Shingle Creek; also the Lowry Avenue Bridge, with five steel bow truss spans, the Forty-second Avenue North Bridge, of the same general type, and the Cedar Avenue Bridge over Lake Nokomis. He also supervised the rebuilding of the Plymouth Avenue Bridge in 1913 and the Washington Avenue South Bridge in 1905. Grytbak likewise has designed a large number of bridges in St. Paul, the most notable being the Kellogg Boulevard viaduct, built in 1930 and 2,100 feet in length; the Reserve Street Bridge, 1942; and all structures in connection with the widening of Kellogg Boulevard between Sibley Street and Seven Corners, 1928–36.

[69] Interview, March 27, 1940, in Minneapolis. Frederick T. Paul, city engineer in Minneapolis, co-operated in designing this bridge under the direction of N. W. Elsberg.

the location rather than of the foundation conditions that existed.[70]

V

While Chicago and the Twin Cities are the major bridge centers in our story, there were others where the influence of Norwegian engineers was significant. The largest city in the Pacific Northwest and one of the most important seaports on the Pacific coast is Seattle, located on the east shore of Puget Sound. The city was ravished by fire in 1889, and after that date experienced a tremendous growth, one phase of which was the building of bridges. Located in an almost unbelievably beautiful region, where mountains, water, and evergreens are the chief scenic features, Seattle rises from the shores of the sound and of inland lakes, presenting a series of hills and valleys that are at once an invitation and a challenge to the bridge-builder. In addition, Lake Washington is linked with Puget Sound by a ship canal more than 8 miles long, which passes through Lake Union in the north central part of the city and connects with the sound by means of locks. This canal within the city must be kept open for shipping and it calls for a modified form of the Chicago bascule bridge.[71]

When Münster moved to Seattle from St. Paul, he served, it will be recalled, for many years as consulting engineer for the city, particularly on the design and construction of a number of its bridges. Notable were those at Fifteenth Avenue West, Fremont Avenue, Eastlake Avenue, and West Spokane Avenue. For a short time he was also bridge engineer and in this capacity directed the design and construction of the Montlake Bridge over the Lake Washington ship canal. One of Münster's first important jobs in Seattle was the designing of a reinforced-concrete viaduct carrying a street over railroad yards. With the opening of the vast unclaimed tideland areas in the southern

[70] *Engineering News-Record,* 105:49 (July 10, 1930); *Minnesota Techno-Log,* 7:174 (March, 1927).

[71] An effective argument for beauty in Seattle bridges is H. G. Tyrrell, "A Plea for Beautiful Bridges," in Association of Engineering Societies, *Journal,* 54:35–43 (January, 1915).

part of the city, the business interests that moved in demanded street improvements and new facilities for an increasing highway traffic. Under the pressure of these demands, in 1912 the Great Northern Railway Company put up a viaduct carrying the west half of Fourth Avenue south of Jackson Street, clearing the extensive yards of the railroad. Münster designed this viaduct and acted as consultant during the entire period of its construction.[72]

When Seattle decided to build three double-leaf bascule bridges across the Lake Washington-Puget Sound Canal, the federal government, in assuming a share of the cost, put down certain conditions that the city had to meet: the bridges must be of a permanent nature and should give a clear navigation channel of 200 feet as well as a head clearance of 30 feet above the level of the lake. Three of the bridges that were built, at Eastlake, Fifteenth, and Fremont avenues, actually have spans of over 200 feet. The bridges at Fifteenth and Eastlake avenues have no counterweight pits. The head clearance of all three is sufficient to permit small ships to pass without opening the bridge. These bridges followed the general design developed in Chicago but embodied a special arrangement of supports at the trunnion piers, "by which the counterweight is made to do double duty. . . . The bridges, which are . . . of simple trunnion type, have a live-load bearing near the river edge of each trunnion pier, 13 ft. in front of the trunnions, and in closed position each leaf pivots on this bearing instead of on the trunnion." Two of the bridges were begun in 1915 and finished in 1917, and the one at Eastlake Avenue was completed in the spring of 1919. Münster, as consulting engineer, had a major part in designing all three.[73]

As acting bridge engineer in Seattle, Münster also had charge of the bascule over the canal at Montlake Avenue, near the University of Washington. Completed in 1925—four years before the engineer's death—this structure is a fitting me-

[72] *Engineering News*, 67:519–523 (March 21, 1912).

[73] R. A. Rapp, "Three Double-Leaf Bascule Bridges at Seattle, Wash.," in *Engineering News-Record*, 84:718–722 (April 8, 1920).

morial to Münster's long bridge career. The Montlake or Montlake-Stadium Bridge rests on foundations that had been put in twelve years earlier, at the time the canal was built. It was designed according to its location and to the peculiar problems involved. Its span is 182 feet between the centers of rotation of the two leaves and its roadway carries two streetcar tracks. The trunnions of the Montlake Avenue Bridge are a distinctive feature. "By supporting the trunnions on a cantilever projection or bracket extending out from the side of the pier . . . the necessity for a cross-girder was done away with." The bracing around the trunnions and their provision for taking the weight of the floor when the leaves are in open position is also novel. The bridge is at the east entrance of the university campus, and because of the hilly nature of the city, the towers rise more than 100 feet above water and are visible from afar. Considerable attention was given to the design of the concrete approaches and towers, which blend easily into the surrounding architecture.[74]

No discussion of Seattle bridges is complete without reference to the floating, or pontoon bridge across Lake Washington. It is the work of Jacob Samuelsen, who graduated from Christiania's Technical College in 1905. As chief engineer of the General Construction Company, he has figured prominently in the planning and construction of many projects in the Pacific Northwest, including power dams as well as bridges. During World War II he was associated with Henry Kaiser in vital war projects.

VI

The engineer who is destined to be known as the builder of novel, yet sound bridges is John Geist, a native of Bergen. As chief engineer of the Wisconsin Bridge and Iron Company, he was responsible for the spiral bridge at Hastings, Minnesota, and the lift bridge of the Sixteenth Street viaduct in Milwaukee.

The lift bridge at Milwaukee, completed in 1895, connects

[74] *Engineering News-Record,* 95: 826–829 (November 19, 1925).

two densely populated portions of the city by spanning the North Menominee Canal. A 68-foot opening in the clear of the canal was needed for the passage of large vessels to and from the coalyards and other industrial and commercial establishments in the neighborhood. Moreover, because of the high value of the dock property on both sides, an ordinary swing bridge was out of the question. A swing bridge, even if made with unequal arms, would prevent boats from mooring close to the bridge and would obstruct the already narrow channel. It was thought desirable to locate the opening as near the middle of the stream as possible. The city engineer decided to adopt some kind of lift bridge but left the general design to bidders. Geist's design was accepted.

The Geist bridge, built of steel, had two main girders supported by a swinging strut near one end and by rollers near the other. These rollers moved on a stationary curved track of such form that when the strut swung through the arc, the center of gravity of the swinging portion moved back in a horizontal line.[75] When the bridge was fully opened, the floor of the swinging portion formed a gate for roadway and walks. Though actually run by electric motors, the mechanism could be operated by two men using hand power.[76]

Every motorist who crosses the Mississippi at Hastings, Minnesota, has the curious experience of going up a corkscrew approach on the Hastings side of the river before coming to the bridge proper. The Hastings Spiral Bridge, believed to be the only one of its kind, is the ingenious solution of a peculiar problem. The height of the river span would have necessitated on the Hastings side either a long approach or a very steep one. A steep approach is never satisfactory and a long one was out of the question, as valuable business property borders the river.

[75] The motion is like that of two bascule leaves supported and revolving upon horizontal trunnions at their middle points above the piers, but the trunnions are replaced by two pairs of revolving radial struts and guide rollers. *Engineering Record*, 31:256 (March 9, 1895).

[76] The best accounts are by Geist in *Engineering News*, 33:146 (March 7, 1895); and *Railroad Gazette*, 27:649–651 (October 4, 1895).

Geist and others solved the problem by making use of a corner lot and erecting a spiral approach on it.[77]

Mention has been made earlier of Edward Wilmann, Pihlfeldt's predecessor as bridge engineer for Chicago. Wilmann graduated from Bergen's Technical College in 1883. He was one of many engineers to plan the buildings of the Columbian Exposition of 1893 and he has been credited, among other things, with the construction of the Union Station in Washington, D. C.

Hans Ibsen will be remembered for having designed and constructed the double-track steel arch bridge over Niagara Falls for the Michigan Central Railroad. The new structure, the heaviest yet built over the Niagara River, opened to traffic early in 1925, replacing a famous cantilever bridge. It created considerable attention at the time because its two-hinged spandrel-braced arch of 640-foot span embodied advanced methods of construction and was bold in design. Its location at Niagara Falls also placed more than common emphasis on pleasing proportions and generally good appearance.[78]

The new Michigan Central bridge took a slightly different location from the old, just below the city of Niagara Falls; the reason was the necessity for finding satisfactory abutments for the long arch in the walls of the gorge. An arch sprung between gorge walls is the best possible solution of the problem of such a bridge, and the walls in this case are composed of horizontal

[77] *Hastings Gazette,* May 27, 1927; and *Minnesota Techno-Log,* 9:252, 268 (May, 1929). Oscar Claussen, St. Paul city engineer, 1912–20, was consulting engineer for Hastings during the planning of the bridge. He must therefore be credited with sharing the honor of devising the spiral design. The *Minneapolis Tribune,* June 23, 1946, names three possible originators of the spiral idea—H. E. Hortan of the Chicago Bridge Company, Oscar Claussen, and James C. Meloy—but does not mention Geist. Paul Kingston, in "A Bridge Oddity," in *Minnesota Techno-Log,* 9:252, 268 (May, 1929), says that John Geist was the engineer in charge of construction, and that "he had much to do with the actual design of the steel." This, he says, was "only one of the unique bridges on which John Geist worked." He mentions, together with the lift bridge in Milwaukee, the "long spans on the Great Northern Railroad at Albans Falls in Idaho." Kingston adds that Hortan suggested the spiral and Claussen "worked up" the general plan of the bridge.

[78] Good accounts are *Engineering News-Record,* 90:380–386 (March 1, 1923), and 93:716–718 (October 30, 1924); H. Ibsen, "New 640-Ft. Arch Span Bridge at Niagara Falls," in *Canadian Engineer,* 44:139–142 (January 16, 1923); *Engineering Journal,* 8:159–162, and 205–210 (April and May, 1925); *Engineer* (London), 139:490, 492 (May 1, 1925); *Minneapolis tidende,* December 25, 1924.

strata of firm limestones, sandstones, and shales. The floor, too, is unusual, in that it rests on the top chord, thereby forming no part of the arch structure. A total of 7,500 tons of steel went into this bridge, which carries trains 223 feet above water. Interestingly, each half of the arch was erected as a cantilever and was held in place by an eyebar tie running back to an anchorage in the upper part of the cliff's rocky side. The advantages claimed for Ibsen's bridge by the *Canadian Engineer* were that it would carry the heaviest loads at the greatest speeds obtainable and, because of its design, would fit pleasingly into the scenic surroundings.[79] It was developed and constructed under the direction of Ibsen, once a student at Bergen's Technical College and later special bridge engineer for the Michigan Central Railroad. Olaf Hoff served as advisory engineer.

Another designer of railroad bridges is Erik Eriksen, a graduate of Trondhjem's Technical College employed by the Canadian National Railways in the bridge department of the central region, at Toronto. In 1933 Eriksen, as designing engineer, was responsible for the plans of a double-track rigid-frame reinforced-concrete bridge for heavy loading. Providing a clear span of over 72 feet, this is believed to surpass in length other bridges of its kind; it was built under traffic west of Montreal, on the main line between that city and Toronto. It crosses a concrete highway at Vaudreuil and is on a skew, both the railroad and the highway below having a curvature at the crossing.[80]

Prominence has recently come to yet another graduate of Trondhjem's Technical College. He is Ingolf Erdal, formerly with the Scherzer Rolling Lift Bridge Company but since 1936 a member of the consulting firm of Hazelet and Erdal of Chicago. The company, in which Erdal acts as chief engineer, in 1938 won the first prize of $5,000 in international competition

[79] *Canadian Engineer,* 48:101–103 (January 6, 1925). See also H. Ibsen's "Demolition of Niagara Falls Cantilever Bridge," in *Engineering News-Record,* 95:1058–1063 (December 31, 1925).

[80] Alstad, *Trondhjemsteknikernes matrikel,* 207; materials in archives of Norwegian-American Technical Sŏciety, Chicago; *Concrete,* 42:5 (January, 1934); and *Railway Age,* 96:430–433 (March 24, 1934).

for the best structural and architectural design of an elevated superhighway; the contest was sponsored by the American Institute of Steel Construction and attracted nearly 300 designs.[81]

Erdal's bridge career has followed the usual pattern; he has been draftsman, detailer and checker, and designer with private companies and with the Chicago sanitary district. While working for the architectural firm of Holabird and Root, he designed the steel trusses over the ballroom of the Stevens Hotel in Chicago; these trusses support the 20 stories above. With the Scherzer Rolling Lift Bridge Company, he directed the design of six large bascule bridges for the French Railways, two for the city of London, and four in China. The last include the large highway bridge connecting the international settlements in Tientsin, which his company built after an international competition involving 35 European and American firms. In 1939 Erdal's firm won first prize for the most beautiful movable bridge actually constructed in 1938, in another competition sponsored by the American Institute of Steel Construction and entered by more than 200 individuals or firms.[82]

The prize-winning bridge erected by Hazelet and Erdal crosses the east channel of the Saginaw River at Lafayette Avenue in Bay City, Michigan, and it is composed of a long bascule span and two shorter approach spans.[83] The double-leaf skew bascule, affording space for navigation on the river's east branch, is of the Scherzer rolling-lift type. A fixed bridge of deck-plate girder spans covers the nonnavigable west channel.[84]

[81] Erdal to the author, April 22, 1940; Alstad, *Trondhjemsteknikernes matrikel,* 196; *Norwegian-American Technical Journal,* vol. 12, no. 1, p. 14 (July, 1939); interview with Erdal, February, 1941; *Engineering News-Record,* 120:666 (May 12, 1938). According to the *Chicago Tribune,* April 8 and 12, 1938, the elevated highway had a streamlined four-lane roadway lifted above surface congestion by single pedestals made up of two supporting legs. It could be put up without causing heavy property damage. Erdal was pleased that beauty was obtainable without sacrifice of functional efficiency. One notable feature was the roadway's open steel grid floor, which replaced the usual concrete and increased safety by preventing skidding, at the same time providing ventilation and making for a shallower deck.

[82] *Engineering News-Record,* 120:490 (April 7, 1938).

[83] *Engineering News-Record,* 122:827 (June 22, 1939).

[84] Craig P. Hazelet, "Bay City Improves Its Bridges," in *Engineering News-Record,* 123: 238 (August 17, 1939).

VII

Of the engineers thus far discussed all have been prominent and have therefore figured publicly in the designing and constructing of America's bridges. There are many more who, though of subordinate rank, nevertheless have earned a fair measure of recognition in their profession, either because of their particular function or the magnitude of the project with which they were associated.

In 1905 the engineering journals proudly announced what was to be the longest span bridge in history—to carry both highway and railway across the St. Lawrence at Quebec. This ill-fated steel bridge was to have been completed by 1909. Theodore Cooper, the great New York engineer, served as consultant, and designs, calculations, details, estimates and quantities were approved in his office, where Bernt Berger, his chief of staff, personally supervised all these matters. On August 29, 1907, the boldly conceived bridge collapsed. On the day of the disaster Cooper telegraphed to the builders to place no more load on the structure until it had been looked over, but no one dreamed that collapse was imminent. In the C. C. Schneider report that resulted from an investigation of the accident, the general opinion of engineers was confirmed: the bridge had turned out to be some 20 per cent heavier than was contemplated by the stress sheets.[85] Cooper and Berger were cleared of any guilt.

Despite the failure of the first attempt to throw so vast a bridge over the St. Lawrence, the task was taken up again, and in September, 1917, the engineers were ready to hoist the central span—weighing about 4,950 tons—between the cantilever arms at either end. In what was said to be one of the "greatest feats of bridge engineering the world has ever seen," the work was completed on September 20; a clear distance of 1,800 feet—the longest span in the world between main piers—was finally bridged. All of the lifting apparatus—hydraulic

[85] *Engineering Record,* 51:268–274, 368–370, 408 (March 4, April 1, 8, 1905), 56: 249 (September 7, 1907); *Engineering News,* 60:153 (August 6, 1908).

machinery furnished by Watson Stillman — was designed by Carl Wigtel.[86]

An equally notable achievement was that of Einar B. Bergendahl, a native of Vadsø, in planning and building the famous Delaware Bridge between Philadelphia and Camden, New Jersey. Completed in 1926, this was for a time the world's largest suspension bridge. It was jointly built by the states of New Jersey and Pennsylvania, and it became a vital link in highway traffic between two populous cities as well as on a trunk east-west route. A board of three engineers was chosen to design and build the bridge; its chairman was Ralph Modjeski, one of America's greatest builders of bridges. The result of their labors was the spanning of a distance of 1,750 feet with a bridge allowing for a six-lane roadway and four streetcar tracks as well as sidewalks. Both from technical and aesthetic points of view the bridge was a "distinguished achievement." [87]

The Delaware Bridge at Philadelphia, though referred to in the Norwegian-American newspapers as the work of a Norwegian engineer, is rather the product of a small army of engineers, none of them — if the official records are reliable — Norwegian. *Nordisk tidende,* however, refers to Bergendahl as the man who made the calculations (*beregninger*) for the bridge.[88] He was office engineer for Modjeski in the firm Modjeski and Angier of Chicago, then the largest bridgebuilding concern in the country, and Modjeski was chief engineer of the Delaware project. That Modjeski would delegate much of the work of calculating and estimating to Bergendahl was only natural.[89]

Just as Bergendahl worked with Modjeski, so Hans Henrik

[86] For vivid accounts of this event, see *Railway Age Gazette,* 63:569–573 (September 28, 1917); *Engineering and Contracting,* 48:259–261 (September 26, 1917); *Engineering News-Record,* 79:580–584 (September 27, 1917); *Canadian Engineer,* 33:235–239, 266 (September 20, 1917); *Engineer* (London), 124:381–384 (November 2, 1917).

[87] Of the many able discussions of this bridge, see *Engineering News-Record,* 97: 530–535, 578–584 (September 30 and October 7, 1926); Franklin Institute, *Journal,* 193:1–14 (January, 1922); and Western Society of Engineers, *Journal,* 28:229–248 (June, 1923). The last two articles are by Ralph Modjeski.

[88] February 2, 1922.

[89] For more information about Bergendahl, see *Minneapolis tidende,* July 14, 1927; *Nordmands-forbundet,* 15:123 (1922); *Scandia,* June 2, 1917; and *Skandinaven,* August 17, 1917.

Rode was an assistant to Gustav Lindenthal, another outstanding figure in American bridge history.[90] A native of Røros, Rode was a graduate of the Hanover Polytechnicum. During his early years in America he was supervisor of design for McClintic-Marshall Company and thus had charge of the design of the New York Connecting Railroad, including the Hell Gate Bridge — at the time the longest and heaviest steel arch in the world and the most important part of the connecting railroad. He supervised the design and was field inspector for the Kentucky River High Bridge and took an active part in developing plans for Lindenthal's competitive design of the Quebec Bridge. After a period as chief engineer in a German firm, Rode was called as professor to Norway's Institute of Technology. But during 1924–26 he was back in the United States with his former chief, this time as resident engineer in charge of the Burnside, Ross Island, and Sellwood bridges built for Multnomak County at Portland, Oregon. Of these bridges, the Burnside over the Willamette River has a large bascule span. The Ross Island Bridge is characterized by its graceful appearance and ingenious cantilever scheme; with approaches it is 4,307 feet long and the central part has a channel span of 535 feet.[91] The Sellwood Bridge is distinguished by continuous girders over four openings. Rode, who later met death in an automobile accident in the Tyrol, was highly regarded by Lindenthal.

Aksel Andersen was destined for a role not unlike that of Rode — as assistant bridge engineer and professor in Norway's Institute of Technology. He is identified chiefly with the George Washington Bridge over the Hudson. But his career in America includes much more. A graduate of Christiania's Technical College and a fellow of the American-Scandinavian Foundation, Andersen completed his studies at the Massachusetts Institute

[90] Lindenthal prepared the memoir of Rode in American Society of Civil Engineers, *Transactions*, 95:1594 (1931).

[91] *Engineering Record*, 69:734–736 (June 27, 1914); *Engineer* (London), 120:495–497 (November 26, 1915); *Nordmands-forbundet*, 19:340 (1926); *Engineering News-Record*, 95:584 (October 8, 1925); *Western Construction News*, 2:28–31 (February 25, 1925).

of Technology and the University of Wisconsin.[92] Finding employment — after the customary variety of positions, one under Lindenthal — with the Port of New York Authority during the years 1925–32, he became assistant engineer of design and served in this capacity on the George Washington Bridge. His work consisted of directing, under the engineer of design, the greater part of the calculating, designing, and estimating. The 3,500-foot structure, completed in 1931, displaced the Delaware Bridge as the longest suspension in the world.

The Washington Bridge was the first to provide a highway connection between New York City and the suburban districts of northern New Jersey; it crosses from Fort Washington Point, on the New York side, to the borough of Fort Lee on the Jersey shore. In arrangement and detail the bridge is simple, and from an aesthetic point of view, a work of art.[93] Something of its tremendous size is grasped when one considers that it is twice the length of the Delaware Bridge span and has eight auto lanes, two lanes for pedestrians, and four tracks. Its towers rise to great heights and it provides sufficient clearance for even the largest seagoing ships on the Hudson River. The wires used in each of its four cables, to mention merely one detail, number 26,000; and the cables are able to support ten times as much weight as those of the Brooklyn Bridge. It operates on a toll basis, the method also employed to pay for the tunnels sponsored by the Port Authority.

According to a Norwegian engineer who worked on the Washington Bridge, the best possible engineers were employed, no matter where they were summoned from. The engineering department of the Port Authority was therefore called the "foreign department," and in it Norwegians were probably in

[92] Information about Andersen's career was obtained from letters from Andersen to the author; material in the archives of the Norwegian-American Technical Society, Chicago; and *Scandia*, July 8, 1938.

[93] *Engineering News-Record*, 99:212–217 (August 11, 1927), and 107:640–645 (October 22, 1931). Ole Singstad was consulting engineer for the vehicular tunnel approach. Volume 97 (1933) of the *Transactions* of the American Society of Civil Engineers is given over entirely to the Washington Bridge. A most significant section is "George Washington Bridge: Design of Superstructure," by Allston Dana, Aksel Andersen, and George M. Rapp, p. 97–163.

the majority.[94] In addition to Andersen, who was right-hand man to the chief engineer in the laying of plans, mention should be made of H. C. Borchgrevink and Arne Lier, who participated in the vast project.[95]

Andersen also made, under the advisory engineer of design, studies and estimates for the Raritan Bay Bridge; he worked out the preliminary design and estimates for the Outer Bridge crossing and Goethals Bridge, and directed in part the preparation of contract drawings, co-operated with architects in the development of various design features, and checked the contractors' working drawings and other projects.[96] When the Kill van Kull Bridge between Bayonne, New Jersey, and Port Richmond, New York, was undertaken during the depression, Andersen was again assistant engineer of design. The Kill van Kull Bridge, completed in 1932, is a 1,675-foot steel arch costing $16,000,000.[97] Andersen, after serving a short time with Waddell and Hardesty, consulting engineers, was employed from 1934 to 1936 by Ash, Howard, Needles, and Tammen, also consulting engineers in New York City. While with the latter firm he designed, checked, and partly directed the design of shop drawings for the steel structures of the Harlem River Bronx Kills lift and approach spans of the Triborough Bridge in New York. The Triborough project, completed in 1936, joined Manhattan by highway with the growing borough of Queens to the east and Queens, in turn, with the Bronx. These three areas had formerly been isolated by water.[98] Andersen also checked the structural design and contract plans for the Mantua Creek lift bridge, the design for the Cohansey River and Manasquan River bascule bridges, and the proposed Yazoo River Bridge — all in New Jersey. He designed and directed calculations for

[94] Trygve Gimnes, "Norske ingeniører i New York," in *Nordmanns-forbundet,* 25: 38 (1932).

[95] *Nordmands-forbundet,* 20:20 (1927).

[96] *Port of New York,* 7:9 (March, 1928); materials in archives of Norwegian-American Technical Society.

[97] *Engineering News-Record,* 105:640–645 (October 23, 1930); *Engineering and Contracting,* 69:285–289 (August, 1930); and *Engineering* (London), 133:1–4, 59–62 (January 1 and 15, 1932).

[98] *Civil Engineering,* 6:515–519 (August, 1936).

the cantilever structure and 300-foot continuous spans of the Neches River Bridge in Texas; finally, with Robinson and Steinman, of New York, he designed, co-ordinated, and checked the contract plans for the superstructures of the Marine Parkway Bridge in New Jersey.[99] What the brilliant Andersen might eventually have become as a bridge engineer in the New World is a matter for pure conjecture; in 1938 he accepted a position as professor in the Institute of Technology at Trondhjem, believing that "an exchange student should, sooner or later, return to his native land and bring back with him the fruits of his studies and experiences."

Representative of many engineers whose work was done in smaller cities, Knud Sophus Riser, a graduate of Christiania's Technical College, was once chief engineer of the Clinton (Iowa) Bridge and Iron Company. While in this position he designed a bridge across the Mississippi at La Crosse, Wisconsin, that had three fixed spans and a single draw span of 450 feet, and the High Bridge at Clinton totaling 3,300 feet in length. After holding other positions in Detroit and Pennsylvania, he became, in 1901, president and chief engineer of the Grand Rapids (Michigan) Bridge Company; later he went into private practice in Grand Rapids, where he won the reputation of being the "court of final resort" in all problems involving steel design.[100]

The long list of significant bridge engineers is by no means exhausted. Hilmar Andresen, a graduate of Christiania's Technical College, was for almost fifteen years bridge designing engineer for the city of Chicago. Ralph Eng, structural engineer with Waddell and Hardesty in New York City, played an important role in the building of the Jamestown Bridge in Rhode Island, the St. George Bridge in Philadelphia, and the Thomas Circle Underpass in Washington, D. C. Another graduate of Christiania's Technical College, L. E. Sangdahl, was once assistant engineer in the bridge and building department of

[99] Information supplied by Aksel Andersen.
[100] American Society of Civil Engineers, *Transactions*, 96:1537 (1932).

the Northern Pacific, with office at Glendive, Montana; in this capacity he did much pioneer work with railroad bridges as well as shops and tracks. Later becoming chief engineer of the Milwaukee Bridge Company, Sangdahl was placed in charge of the construction layout of the Belle Island Bridge at Detroit. And George Kristian Parman, a graduate of Christiania's Technical College who became bridge designer for the Union Pacific Railroad Company in Omaha, designed, over a period of thirty years, most of the standard bridges built by his progressive employers.[101] These men, by overcoming obstacles that would hinder normal transportation, have also woven their lives unmistakably into the fabric of America's growth.

[101] Resumé supplied by G. K. Parman. He takes particular pride in the planning of the Spokane, Washington, passenger terminal.

A REVOLUTION IN TUNNELING

WHILE bridges have evolved from the primitive structures of early man and have a history spanning every known means of transportation, tunnels and subways belong peculiarly to our own age. They are a part of the story of the railroad and the motor vehicle—both of recent origin. In their construction, therefore, inventiveness and novelty play a part that is a vital one when no large body of slowly accumulated experience is at hand to guide the engineer. And the men who pioneered in this branch of transportation, while still embarking on new projects and meeting problems peculiar to local conditions, yet recognize that the major obstacles involved in underground travel have been met and overcome; their task today is largely one of perfecting and improving tunnels that were only recently completed. In the saga of tunnel and subway building American engineers have been conspicuous leaders, though they have borrowed much from English experience; and among these engineers Olaf Hoff, Ole Singstad, and Sverre Dahm were pioneers of unquestioned prominence.

I

The underwater tunnel originated in England. The first of its kind was driven under the Thames about three miles east of Charing Cross and was completed in 1843 after attempts covering a period of twenty-five years. The successful engineer, M. I. Brunel, invented a strange device known as a "shield" which was used to drive tunnels in soft ground. The tunneling procedure begun by Brunel and developed by P. W. Barlow and J. H. Greathead can best be described by comparing it with the

wood-boring worm, which in fact was supposed to have suggested the shield method to Brunel. The worm, as it bores its way through wood, secretes a lining which prevents the wall of the passageway in back of it from caving in. In a similar manner the shield leaves behind it a tube of cast iron or steel, made up of narrow rings which constitute the lining of the completed tunnel.

The use of compressed air, now a regular feature in shield tunneling, is credited to Thomas Cochran, who patented the procedure in 1830. Compressed air is used both for sinking shafts and for tunneling under water; it permits work to proceed in the dry by holding back the water that constantly threatens to pour in. Its chief disadvantage is that it prevents the tunnel laborers or "sand hogs" from working for more than a few hours at a time.

With the use of the improved Greathead shield and of compressed air, English engineers were able in 1869 to drive the second Thames tunnel, the little Tower subway, in the short span of eleven months. In this project the shield method as it is known today was employed in all its essentials.[1]

How the shield works can best be understood by observing one in action. After shafts have been sunk and the shield lowered, it is started on its course. As the earth is removed in front, the shield is forced ahead by a row of hydraulic jacks around the end of the finished lining. The outer rim of the shield is built as a blunt cutting edge that also trims the tunnel. Running back from the cutting edge is a thick steel cylinder plate about 15 feet long which supports the freshly tunneled ground between the finished lining and the cutting edge. When the shield has been driven forward by the jacks about 2½ feet, a lining ring is put into place. Jacks are released several at a time, a segment of the ring is placed by an erector and securely bolted to other segments, and the jacks are shortened and replaced. This routine is repeated eleven to fifteen times for one ring, which

[1] Kirby and Laurson, *Modern Civil Engineering,* 171–174.

thus constitutes about 2½ feet of tunnel. An interior lining of concrete is later applied.[2]

The shield might seem, from this description, a kind of steel monster operating without human assistance. In reality it is bustling with life. Doors can be opened, permitting workers to remove the soft dirt in the path of the tunnel. As the shield is shoved forward into the muck of the river bed, ribbons of mud come pouring into the interior. The dirt is carried back on a conveyor and loaded into dump cars. The working chamber of the shield is under air pressure sufficient to hold back the rush of water or dirt while digging is going on. A bulkhead closes the tunnel near the shore, men and material passing in and out of it through air locks.

In the United States the first two efforts at driving river tunnels were unsuccessful. Significantly, both failures occurred at points where Hoff, Singstad, and others later succeeded. The first attempt was under the Detroit River between Windsor, Canada, and Detroit, where a tunnel was to serve as a connecting link between the Michigan Central Railroad and the Great Western of Canada. Begun in 1872 by Ellis Sylvester Chesbrough, city engineer of Chicago, the tunnel was never completed. The river broke through, workers were killed, and the backers became discouraged; they abandoned the project in 1873.[3]

II

The obstacles at Detroit were overcome by Olaf Hoff when he solved the practical problems involved in laying a tunnel in a prepared underwater trench. He thus contributed to the most revolutionary development in tunneling since the discovery of the shield and the use of compressed air. As vice-president and engineer of Butler Brothers-Hoff Company, he worked out plans that supplemented and altered the bold and original idea

[2] S. A. Thoresen, "Tunnel Lining of Welded Steel," in *Iron Age*, 125:989 (April 3, 1930).

[3] Kirby and Laurson, *Modern Civil Engineering*, 175. For the detailed story of discouragement and defeat, see E. S. Chesbrough, "Sketch of the Plans and Progress of the Detroit River Tunnel," in American Society of Civil Engineers, *Transactions*, 2:85–91 (1872–1874); and "Detroit River Tunnel," in *Transactions*, 2:233–238.

of another engineer, and was later rewarded by seeing his name linked with the new and ingenious techniques.

Hoff entered upon his work at Detroit after an extensive and brilliant career. He was born at Smaalenene in 1859 and graduated from Christiania's Technical College with the highest honors ever granted by that institution. He left for America in 1879 and entered the Keystone Bridge Company as assistant foreman in one of the firm's Pittsburgh shops. Transferred to the drafting room, he was rapidly promoted to assistant chief engineer. After a period with the New York Central and Hudson River Railroad, 1901–05, he formed a new company in New York with Butler Brothers of St. Paul to develop his plans for laying the subaqueous tunnel at Detroit. Hoff was to supervise the work of construction if his firm received the contract and to have a financial interest in the company.[4]

The Michigan Central Railroad, after vainly trying for years to reach an agreement with the Grand Trunk (formerly the Great Western) Railway for jointly constructing a bridge or tunnel entrance into Detroit from Canada, finally decided to build a double-track tunnel under the Detroit River for its own use. All through traffic on the Michigan Central, Grand Trunk, and Pere Marquette was being ferried across the river that divides Windsor, Ontario, from Detroit — at no little expense and inconvenience to the railroads. In the late 1860's the Michigan Central and Great Western lines had agreed to build a tunnel jointly and for this purpose had organized the Detroit River Transit Company, which was to own and operate the underwater connection. It was shortly thereafter that Chesbrough was employed to drive a tunnel by means of the familiar shield method.[5] Early in the twentieth century, interest once more

[4] American Society of Civil Engineers, *Transactions*, 89:1623 (1926); *Who's Who in America*, 13:1590 (Chicago, 1924–25); *Nordisk tidende*, November 10, 1921; *Minneapolis tidende*, December 26, 1924; *Morgenbladet* (Christiania), October 26, 1913; *Norwegian-American Technical Journal*, vol. 1, no. 4, p. 5 (December, 1928); *Harper's Weekly*, 56:22 (March 23, 1912); *Norwegian-American* (Northfield), April 25, 1913; and information received from F. J. Vea of Madison, Wisconsin, a brother-in-law of Hoff.

[5] "The Detroit River Tunnel of the Michigan Central," in *Railroad Gazette*, 40:149–152 (February 16, 1906). This is the first installment of a serial record.

focused on the need of a tunnel which would not only provide a link between Canada and the United States but, more significantly, facilitate an uninterrupted rail connection between East and West by way of Detroit.

In 1904, William J. Wilgus, then vice-president of the New York Central, anticipating the successful electrification of his railroad's terminals in New York City, suggested the feasibility of an electrically operated tunnel under the Detroit River. Subsequent discussion favored a tunnel to consist of two separate and single-track tubes, making use of electricity as a driving power. Shortly thereafter the Detroit River Tunnel Company was organized, and in July, 1905, an advisory board of engineers, composed of Howard A. Carson, W. S. Kinnear, and Wilgus, who was chairman, was engaged to plan construction and electrification. Kinnear was charged with local authority as chief engineer, a position which he occupied very competently, and Benjamin Douglas had direct supervision of construction proper.

By the fall of 1905, the usual surveys and borings had been completed and the alignment and profile of the tunnel had been determined. The next problem facing the board was the choice of one of four suggested types of construction. Wilgus said:

> [It] was found that if possible some other method than the usual compressed air shield-driven type should be employed, in the interest of life and health of workers and time and expense of construction. To that end Mr. Howard A. Carson suggested the use of precast pipe sections laid in a dredged trench. This did not appeal to me because of anticipated difficulty in effecting tight joints under water and securing continuity of support. . . . The idea came to me of lowering forms in sections in a prepared trench, around which concrete deposited from the water surface by means of the tremie [*pipe*] would harden and seal all joints, thus enabling the interiors to be pumped out successively and the concrete lining laid in the dry.

Wilgus prepared sketches of the tunneling method based on this idea, expanded and drew these to scale, made estimates of cost, and submitted the scheme to his colleagues on the board and to other engineers, including Olaf Hoff.

The consensus was that my method, though bold, was practicable. The Board thereupon voted to include it, as well as Mr. Carson's and the compressed air shield-driven methods, in the requests issued for bids on alternative designs. Each bidder was required to submit supplemental plans by him deemed necessary to more clearly explain the manner in which he proposed to carry out the work in conformity with the method of his selection. The lowest acceptable bidder proved to be the Butler Brothers Construction Company. . . . Its proposition was based on the employment of the method of which I was the inventor, and was accompanied by the required supplemental plans, prepared by Mr. Hoff, illustrative of the ingenious manner in which the contractor proposed to build, transport, deposit, join and surround the forms in the prepared trench, all in conformity with the tunnel specifications I had prepared. . . . I took out a patent on my invention, in the application for which I was joined by Mr. Carson, and a free license thereunder was given the tunnel company. . . . The idea was presented to the world.[6]

Before the contract was closed Butler Brothers-Hoff Company asked for and received protection against any claims that might arise from the use of the Wilgus design, and the patent indemnity clause in the contract was accordingly modified.

The revolutionary scheme proposed by Wilgus was known as Design A and that of Carson as Design B; Design C was a modification in details of Design A, while the compressed air-shield method was labeled Design D. The contractors were given the interesting option of "selecting any one of the four methods for the subaqueous work, or submitting entirely new designs, or modifications of those suggested, restricted only to a compliance with certain conditions regulating stability, clearances, workmanship, etc." The plan worked out by Hoff was a "modification of Design A, embodying some of the elements of Design C, accompanied by a large amount of detail covering the methods to be used in the prosecution of the work." The contract was "unique, particularly with reference to the sub-

[6] A letter to the writer from Wilgus, August 13, 1945, thus takes one behind the scenes and tells more vividly than the official records the origins of the Detroit tunnel idea. Statements in the Wilgus letter have been checked against documents in the possession of the Engineering Societies Library, New York City, by Harrison W. Craver, director. See also Wilgus, "The Detroit River Tunnel, between Detroit, Michigan, and Windsor, Canada," in Institution of Civil Engineers (London), *Minutes of Proceedings,* 185:2–36 (1911).

aqueous section, leaving the working out of details to the ingenuity of the contractor."[7] Work was begun on October 1, 1906, and completed July 1, 1910.

Briefly considered, the novel underwater portion of the Detroit Tunnel was laid in the following manner: A trench was first dredged in the river bottom and supports placed in it to receive twin-tubed steel forms in sections, each about 260 feet in length, that were built and launched in a shipyard, towed like barges to a position above the trench, lowered into place, and connected together by divers. Wooden sides and cross diaphragms of steel restrained the concrete which was later poured around the forms through pipes, or tremies, from a floating concreting plant anchored in the river. After several lengths of tunnel had been laid, they were unwatered, leaks were stopped, and an inner layer of concrete, reinforced with steel rods, was added in the dry and without the use of compressed air. The combination of surrounding concrete and the firm lining inside prevented water seepage and provided resistance against the shock of trains passing over rails and ties that rested directly on the underlying concrete. In this manner it was possible to enlarge the diameter of the tunnel from 18 to 20 feet.[8]

III

The tunnel, once construction was begun, attracted considerable attention, the *Engineering News* in the fall of 1907 designating it the "most novel and interesting tunnel works now in progress." The technical journals called special attention to the length of the river portion, which measured over 2,600 feet, the difficulties of construction inherent in the project, and the methods of setting grillage and depositing the exterior concrete which made of the completed tunnel one great monolithic mass. Both Wilgus and Kinnear in their exhaustive accounts paid

[7] See Wilson Sherman Kinnear, "The Detroit River Tunnel," in American Society of Civil Engineers, *Transactions*, 74:288–356 (December, 1911). The quotations are from pages 303, 304, and 356.

[8] Other accounts of the Detroit Tunnel are James C. Mills, "The Detroit River Tunnel," in *Cassier's Magazine*, 33:337–349 (January, 1908); *Engineering News*, 58:453–455 (October 31, 1907); and *Engineering Record*, 60:678–680, 719–722 (December 18 and 25, 1909).

tribute to the skill of the contractors who gave form to an idea. In the discussion that followed the Wilgus paper, E. W. Moir said that his British firm, S. Pearson and Son, which had tendered a bid, would have made a "handsome profit at their price if they had been as clever as the firm who obtained the work" and added that since the author of the paper "gave such great credit to the contracting staff," he was "sorry to see that the names of individual members of it did not appear." These sentiments were echoed by E. W. Monkhouse, who tried to place himself mentally in the position of the one laying sections 260 feet long on the grillage in moving water and then joining these one to another with great accuracy.[9] August Gundersen, Hoff's chief assistant, went much farther — indeed too far — in stating that "none of the four designs submitted by the Board was used in the actual work," for they "did not solve the old question 'how to build a subaqueous tunnel in an excavated trench.' The first solution of this problem as carried out at Detroit, is entirely due to the ability of Mr. Hoff."[10]

It is well known that contractors regularly work out their own methods to put into effect a given design, within the limits of specifications and always with an eye to reducing costs. In the case of the Detroit Tunnel, however, the engineer of the contracting firm went much further — both because of the freedom afforded by the tunnel company and the very newness of the design that was employed. Several "ingenious measures" were credited to Hoff by Wilgus: "(a) the bracing of the forms to prevent distortion in launching, towing and lowering into place; (b) the use of outside planks attached to the forms to minimize the quantity of tremie-placed concrete; (c) the employment of air cylinders to regulate the lowering and placing of the forms; and (d) the adoption of devices for drawing the forms together in the bottom of the trench — all means which this contractor deemed necessary for accomplishing the desired

[9] See "Discussion" following the Wilgus paper, Institution of Civil Engineers, *Proceedings*, 185:45–64 (1911).

[10] See "Discussion" following a paper by Kinnear in American Society of Civil Engineers, *Proceedings*, 37:1169 (1911).

purpose set forth in the contract *at the least possible cost to it.*"[11]

In the light of these and of innumerable other statements, both published and unpublished, concerning the Detroit project, it is of prime importance that Hoff be given the opportunity to speak for himself. Fortunately, he has left a record of his work in the form of a letter published in the *Transactions* of the American Society of Civil Engineers:[12]

> When the firm with which the writer was connected [*Hoff wrote in February, 1906*] received invitations to submit proposals for the construction of the Detroit River Tunnel, he immediately and with assiduity set to work on this intensely interesting problem. At that time he had no knowledge of the numerous patented inventions for building subaqueous tunnels in a trench in the bottom of a river or waterway. . . . Later, having occasion to look the matter up, he was surprised to find a number of patents on such tunnels, mostly impracticable schemes, of doubtful merit, not one of which was ever carried out.

Hoff then proceeds to discuss the designs submitted for bids, stating that all of them contemplated a tunnel two feet smaller in diameter than the one actually built. Analyzing the designs, he also shows their defects. "The result of the foregoing analysis," he concludes, "was the gradual development of the design submitted by the writer, which, together with the specifications and the accompanying proposal, was accepted by the Board of Engineers, and according to which the tunnel was built."

The first object sought in working out his plans, Hoff tells us, "was the elimination of compressed air, with its attendant cost and restrictions in prosecuting the work." He felt, however, that he should be ready to use it in case the outer concreting should be a failure. "The initial step toward the accomplishment of this was a tube of steel of sufficient strength in itself or in connection with the exterior concrete, to resist the water pressure and effectively to prevent its ingress into the tunnel. . . . This shell, at the same time, would constitute an inner form for the exterior concrete."

[11] Wilgus to the writer, September 22, 1945. Italics are Wilgus'.
[12] Vol. 74, p. 361–373 (December, 1911). The letter follows Kinnear's paper on the Detroit Tunnel.

The next step was "to reduce the exterior concrete to a definite quantity—the minimum required—without filling up the whole trench, thus saving a large item of cost. A little study and a few calculations soon demonstrated that this minimum would be the quantity necessary to overcome the buoyancy of the mass in the trench, when the tubes were unwatered, and prevent them from floating up again." Hoff then had to secure his outer form to the steel shell. A solid steel plate seemed to him to be the proper solution, since this would divide the tubes into compartments, which could be filled with concrete, one at a time. "Thus the diaphragms were developed, together with the pocket or compartment principle, to which, in the writer's judgment, the success attained at Detroit is to be attributed. The concrete was discharged through the tremies under a head; its lateral flow was confined to the exterior sides of the compartment, and thus it was forced under the steel tubes, affording them a reliable and satisfactory bearing."

One peculiarity of Hoff's tunnel system is that "the load on the bottom of the trench during construction will be as great as, or greater than, the maximum load of the completed tunnel when in use. In other words, the weight of the water inside the tubes is equal to or greater than, the weight of the concrete lining and the live load." Because of this and his uncertainty as to the quality of the concrete, he increased the thickness above the tubes more than was necessary. The quality of the concrete, "to the very top surface," proved to be good.

"Of the greatest importance," Hoff continues, "was the problem of lowering the tubes into the trench and keeping them always under absolute control. To this end the four air cylinders were devised, and served the purpose most successfully. They were of such size as to have a combined buoyancy, when submerged, slightly in excess of that required to hold a tunnel section in suspension." Water was admitted to the center or adjustment compartment of each cylinder to lower the mass into the trench.

When the tubes had been sunk in the trench and concrete placed under them at the ends and at least at one point in the middle, the air cylinders could be released. "This was done by first filling them with water, which caused the weight of the tubes to be gradually transferred from the cylinders above to the concrete below." Then the cylinders were brought to the surface by forcing air into the center compartments and by using derricks. Hoff explains how the tubes were held against the river current during the sinking. The plans originally called for anchors of concrete planted in the bed of the river, but the superintendent of construction thought ordinary anchors would serve. The superintendent's plan failing, Hoff was forced to use concrete slabs in a hole dredged out in the river bottom; clay was filled in on the top.

The time needed "for taking a section from its moorings, placing it in position over the trench, attaching it to the anchor lines, filling the tubes, adjusting the air cylinders, lowering the section to the bottom of the trench and pulling it home, so that the keys could be inserted in the pilot pins, thus locking the sections together . . . took from, say 8 A.M. until 8 or 9 P.M., after the first two or three sections had been sunk. The lining up of the tubes at the outer end, and the bolting up of the flange connections, could then be commenced the next day." The bolting process, performed by divers, generally required two days, since there were about 50 bolts to the joint, or 100 bolts to a section.

A significant innovation was made at Detroit in placing concrete under water by means of the tremie. Properly constructed and operated, Hoff explains, concrete may be placed so that "the great mass of it will not come in contact with the water at all, after the first surface of concrete has been formed. This is accomplished by mixing it so wet that the mouth of the tremie at all times is buried in it, thus sealing the end of the pipe and controlling the flow by raising or lowering the tremie in the concrete, and by confining its lateral flow in compart-

ments which are filled one at a time, the concrete all the time seeking its level within the compartment."[13]

In some cases the bottom of the trench became soft when excavated. To secure a proper foundation for the tubes where this occurred, wooden sheeting was driven down into the dirt and the width of the base was increased. Tremies were then lowered, under their own weight of from 7 to 8 tons, as far as they would go through the soft clay; "they would generally go down to within 1 or 2 ft. of the rock bottom at a depth of from 85 to 90 ft. below the surface of the river. A little extra force was used to put them down as far as possible, and concrete was then deposited until it reached the underside of the diaphragms. In this manner—a series of piers, 6 ft. in diameter, was built up under the tubes, two to a pocket longitudinally of the tunnel, and three rows, one for each tremie; that is, there was one row under the center wall and one under each of the side-walls of the tunnel."

The tubes were unwatered by pumps, which were installed in the first section of the tunnel before it was launched, remaining submerged more than seven months before they were started. No difficulty was encountered; the unwatering usually "required 3 hours per tube in a section, or 6 hours for two adjoining tubes." Hoff explains also:

> One object in developing the adopted design, was to reduce the use of divers to a minimum. Diving is expensive work, and frequently unreliable. The only physical labor performed by divers was the temporary attaching of the steel tubes to the grillage in the trench, the bolting up of the joints of the tube sections, and the disconnecting of the air cylinders. In other respects, divers were only used as "eyes to see with," that is, as inspectors to report conditions. The total cost of diving at Detroit was only about one-half of 1% of the total cost of the river tunnel.

Commenting on workers and accidents, Hoff states that "the construction of the whole river section was singularly free from accidents, not a single fatality occurring in connection with

[13] In another article by Hoff, "Laying Concrete under Water in the Detroit River Tunnel," in *Engineering News,* 63:318–321 (March 17, 1910), reasons are given for the success of the method of concrete laying at Detroit.

the river work — a striking contrast to the general experience when compressed air and shields are used. It may be of interest to note that three of the largest concerns in the country writing Employers' Liability Insurance offered to give protection at about one-third the rate they charged for tunnel work done under compressed air."

Hoff estimates, in discussing the advantages of his tunnel, that about $2,000,000 was saved at Detroit because of the small labor cost involved; and this was not offset by a greater cost of materials. He argues, too, that a capitalized saving in the railroad's annual cost of operation was effected, since his tunnel provides a roadbed some 15 feet higher than would have been the case with a deeper shield-driven tunnel — thus reducing the vertical lift of tonnage. About 1,000 feet of approach tunnel on the Canadian side was also saved, and about 750 feet on the American side.

"After two years of constant effort and sacrifice of health to make this new and untried method of subaqueous tunneling a success," Hoff concludes, "it was a source of the greatest regret to the writer that he was unable to remain with the tunnel and witness its completion; circumstances beyond his control made it necessary for him to retire from the contracting firm in October, 1908, after Section No. 6 had been sunk, and after practically all problems presenting themselves with this work had been solved." [14]

How Hoff worked has been described by one of his assistants at Detroit. The tunnel plan "occupied many pages in his neatly-kept book of sketches and calculations. Every detail was worked out, not only those pertaining to the strength of the finished structure but also every little accessory and arrangement in connection with the execution of the work. So when the job was turned over to the construction forces everything dovetailed; it all worked out as calculated, with no lost time. It was a complete success." No detail, however small, was overlooked by Hoff, and his sandy hair and keen blue eyes behind gold-

[14] American Society of Civil Engineers, *Transactions*, 74: 361–373 (December, 1911).

rimmed glasses became a familiar sight to the tunnel workers during the months that he supervised construction at Detroit.[15]

The sudden disappearance of Hoff from the tunnel scene was caused by a sharp clash he had with Butler Brothers. Hoff maintained that, after the success of his plans had been demonstrated beyond all doubt, disagreements about the disposal of machinery resulted in an effort by his partners to deprive him of his predetermined share of the company's financial return from the project. This share amounted to one fifth of the profit, which would have been about $1,500,000. When Hoff's salary, too, was cut to very little, he brought suit against Butler Brothers. Whatever the legal or other merits of his claim, a financial settlement was made out of court. One result of Hoff's troubles at Detroit was that during his second great tunnel undertaking he made all necessary arrangements with a bank, kept the financial strings in his own hands, and realized about $1,000,000 as his share of the profit.[16]

IV

In the various articles describing the Detroit River Tunnel, Hoff's name was mentioned only in passing. With the beginning of his next project, a subway tunnel under the Harlem River in New York, it was given a prominent place.[17] Now a member of the contracting firm Arthur McMullen and Hoff Company, he was made consulting engineer for the Harlem Tunnel; his firm received the building contract and his patented method of tunneling was employed.[18]

The Harlem River borders Manhattan Island on the north. The new tunnel, at Lexington Avenue and One Hundred Thirty-fifth Street, crosses the river where it is some 600 feet wide

[15] Guttorm Miller of Detroit to the writer, January 11, 1941. For a sketch of Hoff, see Flynn Wayne, "Olaf Hoff — His Work," in *National Magazine*, 38:51 (April, 1913).

[16] Information furnished by F. J. Vea of Madison, Wisconsin.

[17] "Subway Tunnel under Harlem River," in *Engineering Record*, 68:556 (November 15, 1913). See also Wayne, in *National Magazine*, 38:51.

[18] Patent numbers 907,356, subaqueous tunnel (December 22, 1908); 907,357, method of sinking subaqueous tunnels (December 22, 1908); and 972,192, apparatus for subaqueous pile driving (October 11, 1910).

and 26 feet deep at low tide. Several factors called for the trenching method. It was not permissible to block navigation on the river, and therefore open cofferdams and pneumatic caissons, which tend to obstruct the channel, could not be used. The thin roof of the river bed and the extremely soft ground under the river, it was believed, would have made shield tunneling difficult. These and other factors called for a method different from the customary one, "and eventually the sunken tube method was adopted on considerations of safety, rapidity, economy and convenience, and it was built by a modification of the design and method first used by Olaf Hoff . . . under the Detroit River at Detroit, Michigan."[19]

The Harlem River Tunnel, 1,080 feet in length, is composed of nearly equal sections containing four tubes instead of two as at Detroit. These tube sections were built on shore, floated into place, sunk, and bolted up under water as in the first undertaking. Similarly, too, concrete was poured through tremies and the tubes were unwatered in the manner described by Hoff. Little that was basically new was added in the Harlem Tunnel, but it nevertheless utilized a number of improvements in construction and proved the adaptability of the trench-and-tremie methods to this location. Each four-tube section was assembled on a staging about one mile from the tunnel site. When it was completed and ready to be sunk, narrow scows were placed between the rows of piling that made up the staging. When the tide rose, the scows lifted the tunnel section from its staging and towed it into the river's stream. The scows were then scuttled and the section left afloat to be towed by barges in the usual fashion to the place where it was to be sunk.

A section was first lowered in the middle of the river, rather than at the shore, and half of the river was closed to navigation. At Detroit the first section had plunged endwise instead of settling evenly, despite the use of buoyancy cylinders. At the

[19] Frank W. Skinner, "The Harlem River Subway Tunnel, New York," in *Engineering* (London), 104:32 (July 13, 1917). Skinner's detailed report of the tunnel is carried in serial form, appearing also p. 83–87 (July 27, 1917). See also *Nordisk tidende,* August 22, 1912.

Harlem River, the sections had, in addition to the cylinders, partial bulkheads placed on the heavier ends and extending halfway down from the upper part of two of the tubes. As water poured into the tubes, the heavier end of the section tipped downward until the bulkheads touched water, whereupon the air trapped back of the bulkheads buoyed up the lighter end and the section leveled off. The air was then allowed to escape through a hose leading to one of the barges. When all but about a foot of the section's top had submerged, the tubes sank abruptly until the buoyancy cylinders, which were strapped at the ends, made contact with the water. When water was admitted into the chambers within the cylinders, the tunnel piece sank beneath the surface; derricks, which then took command, lowered it slowly and accurately into place on bents which had been laid in the trench on the river bottom. The sections, it is said, came within a fraction of an inch of true position.[20] The diaphragms of steel, which held the four tubes together during the sinking process, then provided the necessary reinforcement for the concrete that was later poured around the section.

Following the successful completion of the Harlem Tunnel in 1915, Hoff continued to work as before on problems having to do with subway, tunnel, harbor, and bridge construction. He was chief consultant to the Cunard Company when it proposed to construct a steamship terminal in the port of New York, and served in a similar capacity with the New York Central Railroad when the A. H. Smith Memorial Bridge was designed and built across the Hudson at Castleton, New York. When the arch bridge of the Michigan Central was thrown across Niagara River near the falls, he was again called in as consultant. Studious and inventive, he made invaluable contributions in connection with submarine pile driving, the general use of reinforced concrete, floor construction, and numerous other structural features. Varied and significant as his many undertakings were, none matched his performance at Detroit in

[20] *Scientific American,* 109:244 (September 27, 1913). See also vol. 108, p. 286 (March 29, 1913).

working out designs deemed by him essential to constructing a tunnel in a prepared trench.[21] Hoff died in December, 1924, honored as a great and original engineer.

V

Just as Hoff's name is identified with the sunken-tube method of tunneling, so Ole Singstad's is associated for all time with the special tunnel that was developed to carry the automobile. Tunnels for the use of vehicles are of recent origin, the first of importance being the Blackwall Tunnel under the Thames at London, which was opened to traffic in 1897. Others to be built before the extensive use of automobiles were the Glasgow Harbor Tunnel (1895), the Elbe Tunnel at Hamburg (1910), and the Rotherhithe Tunnel under the Thames (1908). The Holland Tunnel in New York was the first of any size or significance built to care for the needs of present-day motor vehicles.[22] As a result this tunnel presented new and difficult problems, the solution of which put Singstad's name on the roster of modern pioneers. Singstad designed the Holland Tunnel, worked out its unique system of ventilation, completed its construction as chief engineer, and operated it for two and a half years after its completion. In subsequent years he acted either as chief engineer or as consultant in connection with the most important vehicular tunnels that were constructed.

The Holland Tunnel and its successors in New York play such a vital part in the life of America's greatest port city that a brief discussion of these tunnels seems essential here. Prior to the building of the first vehicular tunnel under the Hudson River, Manhattan was connected with New Jersey, lying to the west, only by electric-car and train tubes and about fourteen steamboat ferries. With no bridges for many miles up the river,

[21] Asked for an appraisal of the Detroit job, Carl H. Stengel, New York consulting engineer and former partner of W. S. Kinnear, said, "Mr. Wilgus originated the idea. . . . Mr. Hoff developed a practical means of accomplishing the results of the Wilgus idea"; to the writer, September 11, 1945.

[22] S. A. Thoresen, "Constructing the Detroit-Windsor Tunnel," in *Civil Engineering,* 1:613 (April, 1931); Ole Singstad, "Ventilation of Vehicular Tunnels," in World Engineering Congress, *Proceedings,* 9:381–399 (*Public Works,* part 1—Tokyo, 1931).

ferries were overworked to such a point that it was necessary on Sundays and holidays for motorists to wait for hours before crossing the Hudson. And weekdays were only slightly better. As is generally known, the financial and wholesale districts of New York are concentrated in lower Manhattan. Strangely enough, this nerve center was — and still is — linked with the Jersey side by only six railroad and electric-car tubes.[23] In Singstad's own words:

[When] it is borne in mind that on the Jersey side of the river are the terminals of eight trunk line railroads, that the greater part of the population of the metropolitan district is located to the east of the Hudson River, that most of the steamship terminals, both for coastwise and foreign shipping, are located either in Manhattan or in Brooklyn, and also that there are large population centers in New Jersey immediately west of the river, it is quite evident that, when a comparison is made of the volume of traffic crossing the Hudson River with that crossing the East River, the absence of vehicular traffic facilities has been a great hindrance to the development and free movement of the traffic between Manhattan and New Jersey. It was this pressing need . . . which prompted the two states to create the commissions which are now constructing the Holland Tunnel.[24]

Earlier efforts had been made to tunnel under the mile-wide Hudson. In 1874 a western promoter, De Witt C. Haskins, came to New York, raised the necessary capital, and began the first attempt to pierce the river's soft bed. Legal difficulties postponed the project for five years, but finally in 1879 work was begun. Using compressed air but no shield, Haskins failed utterly. Walls and ceilings gave in, 23 men were killed — and the tunnel was abandoned. Eventually, in 1908, it was completed as the McAdoo Tunnel under different engineers.[25] Next, a large English engineering firm sent experts to New York to

[23] Frank W. Skinner, "The Holland Vehicular Tunnel, under the Hudson River," in *Engineering* (London), 124:601–606 (November 11, 1927). This article, which is continued in the issues of November 25 (p. 667–671) and December 9 (p. 735–738), is the most exhaustive study on the subject to be found in the technical journals.

[24] Ole Singstad, "The Relation of Tunnels and Bridges to Traffic Congestion," in American Academy of Political and Social Science, *Annals*, 133:69–71 (September, 1927).

[25] Kirby and Laurson, *Modern Civil Engineering*, 174; *Nordisk tidende*, December 15, 1938.

see what might be done in the way of a tunnel. Plans were drawn up but never executed; the cost was too great.[26]

A bridge had long been considered both feasible and desirable. As early as 1868, Singstad informs us, the states of New York and New Jersey granted charters to a private corporation to build a bridge across the Hudson. Nothing came of this plan. In 1906, at the instance of public-spirited citizens, each state appointed a commission to study the possibility of a bridge to be built with public funds. These commissions concluded in 1913 that it would be economically impracticable to build a bridge where the traffic needs were greatest. They then began a study of the possibilities of a tunnel.[27]

The bridge and tunnel commissioners had made sufficient progress by 1919 to justify the appropriations of $1,000,000 made by each state to begin plans and actual construction of a tunnel. Clifford M. Holland, who was appointed chief engineer of the joint commissions, recommended in 1920 that twin tunnel tubes, each of which would handle two lines of one-way traffic, be constructed under the Hudson.[28]

The plan for a bridge had been discarded for a number of reasons. It was evident, in Singstad's opinion, "that a tunnel is a more suitable and economic type of structure than a bridge, where the conditions are similar to those existing at the location of the Holland Tunnel, and, in fact, for entire Manhattan Island below Central Park." These conditions consist of a waterway over 3,000 feet wide between pierhead lines, low riverbanks, and high land values.

If a bridge were to be built at this location, the cost would be excessive due to the long span, the expensive foundations due to the great

[26] *Nordisk tidende,* December 15, 1938.

[27] Ole Singstad, "The Holland Tunnel," in *Norwegian-American Technical Journal,* vol. 1, no. 3, p. 1 (September, 1928).

[28] It should be made clear that Holland was the genius of the tunnel project. A summary of his report to the joint commissions is found in *Engineering News-Record,* 84:357–364 (February 19, 1920). Singstad, as Holland's engineer of designs, was ably assisted by A. C. Davis, mechanical engineer, and J. N. Dodd, electrical engineer. The more important parts of Holland's report were approved by a board of consulting engineers composed of W. J. Wilgus, J. A. Bensel, William H. Burr, Edward A. Byrne, and J. V. Davies.

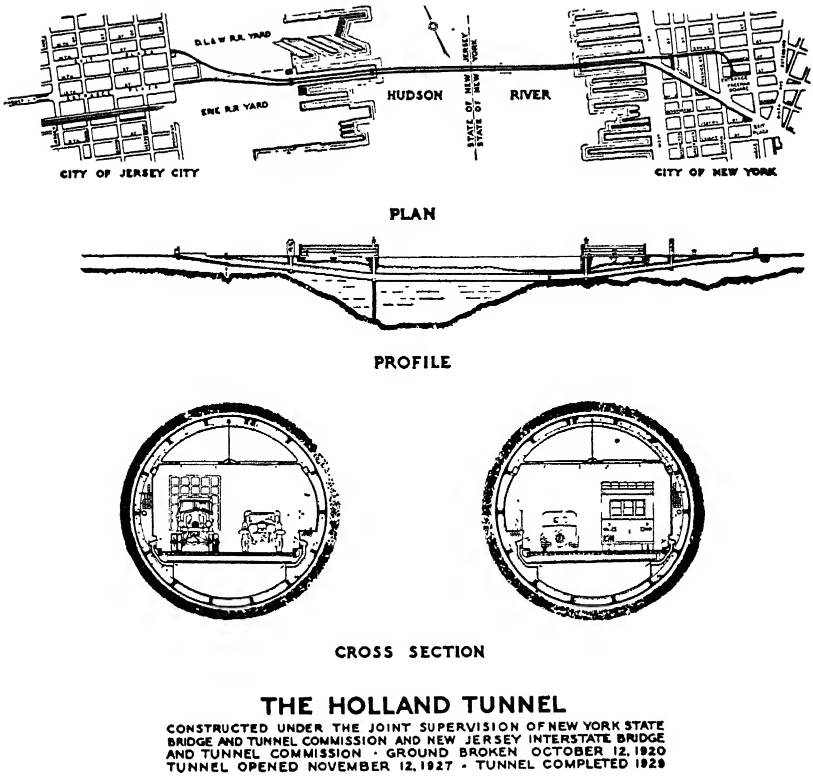
depth to rock . . . and the expensive approaches. A bridge would have to have a clearance of from 180 to 200 feet above mean high water, and its approaches . . . would have to be carried inland as far as Broadway. . . . A long bridge approach also would be detrimental to the real estate values under and in the vicinity of the bridge. With a tunnel it is only necessary to go down a distance of less than 100 feet below mean high water with the roadway due to navigation requirements, so that the approaches would be about one-half as long as those for a bridge. . . . The tunnel further has the advantage that it does not depreciate real estate values in its immediate vicinity, as there is no surface evidence of the structure except in the short distance from the portal to the point where the roadway meets the street surface.[29]

The decision made in favor of a tunnel, Holland lost no time in approaching Singstad. They had known each other from the time the latter was designing engineer of rapid-transit tunnels; Holland was construction engineer on the same projects, and Singstad's abilities had impressed him. Singstad had acquired a broad experience and skill which the brilliant Holland, now chief engineer for the new tunnel, was quick to seize upon. One day in 1919, the story goes, Holland telephoned Singstad and asked him to call at his office. Holland, himself only thirty-six years old, invited the young Norwegian to be his engineer of design.[30] After some hesitation Singstad accepted the proffered post. In 1924 Holland died and was succeeded as chief engineer by Milton H. Freeman. Three months later Freeman died, and Singstad, who had designed the tunnel, carried it to completion in 1927 as chief engineer.

The man who made history in designing and completing the Holland Tunnel and who is now the dean of all tunnel engineers was born at Lensvik in 1882. Following his graduation from Trondhjem's Technical College in 1905, Singstad had left without delay for the United States. In New York he immediately found work with the Central Railroad of New Jersey. He left in the next year for Norfolk, Virginia, where he designed railroad structures and assisted in rail and bridge construction for the

[29] American Academy of Political and Social Science, *Annals*, 133: 73–76.

[30] *Nordisk tidende*, December 15, 1938; an interview signed "H.O." This is the best sketch of Singstad to be found in the Norwegian-American press.



Plan of Holland Tunnel

Queens Midtown Tunnel

Virginian Railway. Returning to the East, he took a position with the Hudson-Manhattan Railroad, preparing designs for work on Hudson River tunnels during 1909–10. He also designed rapid-transit subways and tunnels in New York, in Brooklyn, and under the East River, remaining for seven years in charge of this work and working with Holland for the Public Service Commission of the first New York district. After establishing a sound reputation as a first-class tunnel engineer, Singstad served during 1917–18, in charge of structural design, with the Chile Exploration Company, and in 1918–19 with Barclay Parsons and Klapp, in charge of laying out and estimating a rapid-transit system for Philadelphia. While with the latter firm, he made preliminary designs and estimates and reported on a vehicular tunnel under the Delaware River.[31]

A great deal has been written about the Holland Tunnel, for it began a new chapter in engineering history.[32] Much of what has been written is in technical language and has no great interest for the layman. A few general facts, however, seem to be pertinent here. The new project cost about $48,500,000, each state paying half of the total expense. The tunnel connects Twelfth and Fourteenth streets in Jersey City with the borough of Manhattan at Canal and Varick streets and Broome Street, and operates on a toll basis. The tunnel actually consists of two separate tubes, each with an exterior diameter of 29½ feet; the northern one serves west-bound and the southern serves east-bound traffic. Between portals it is 8,463 feet long.[33]

In planning the tunnel, we are told, two types of construction were considered — the trench-and-tremie, together with other

[31] *Norwegian-American Technical Journal,* vol. 4, no. 1, p. 12 (April, 1931); H. Sundby-Hansen, in *American-Scandinavian Review,* 15:360 (June, 1927); Wong, *Norske utvandrere,* 76; Alstad, *Trondhjemsteknikernes matrikel,* 226; Alstad, *Tillegg,* 63; "H.O.," in *Nordisk tidende,* December 15, 1938; information supplied by Singstad in May, 1941.

[32] In addition to the articles cited in this chapter, there is a lengthy unpublished account of the tunnel, written by Ole Singstad, in the Engineering Societies Library, New York City.

[33] A comprehensive general survey of the Holland Tunnel may be found in *Engineering* (London), 124:601–606, 667–671, 735-738 (November 11, 25, and December 9, 1927). A briefer and less technical account is contained in *Scientific American,* 137:201–203 (September, 1927).

trench methods, and the well-known shield technique. "On account of the heavy river traffic, the soft character of the river bed, and the intensive use of the water front, the shield method was considered the safer and more economical." The tunnel was constructed by first sinking shafts as pneumatic caissons on shore. Shields were started from these shafts, two from the New York side and two from the Jersey side, the shields meeting under the river. "On their way the shields passed through a second set of caissons, which had been sunk in advance of the approach of the shield to serve as foundations for the second set of ventilation buildings located in the river back of the pierhead line. On the New Jersey side, two additional shields were started westward, to carry the construction back to points where excavation by the open-cut method could be successfully carried on."

Work in compressed air required pressure up to 47½ pounds per square inch above atmospheric pressure, involving "756,000 decompressions of men coming out of the compressed air workings." The job was finished with only 528 cases of "bends," and none of these cases resulted in death.[34]

However interesting the detailed designs of the tunnel itself, the tools employed, and the problems inherent in driving a shield for tubes of great diameter, these must give way to another feature — the novel system of ventilation which is Singstad's unique contribution and a pioneering feat of real significance.[35] Fortunately, Singstad has told in detail the story of how this system evolved under his direction. Because of its importance, we quote at length from a paper presented by Singstad before the World Engineering Congress at Tokio in 1929.[36] In this paper is explained how the chemist and physiolo-

[34] Ole Singstad, in *Norwegian-American Technical Journal*, vol. 1, no. 3, p. 1–3, 10 (September, 1928). For detailed information on work under compressed air, see Singstad, "Industrial Operations in Compressed Air," in *Journal of Industrial Hygiene and Toxicology*, 18:497–523 (October, 1936).

[35] For other accounts, see "Studies and Methods Adopted for Ventilating the Holland Vehicular Tunnels," in *Engineering News-Record*, 98:934–939 (June 9, 1927); and "Ventilating the Holland Vehicular Tunnel," in *Heating and Ventilating Magazine*, 23:79 (August, 1926).

[36] Singstad, in World Engineering Congress, *Proceedings*, 9:381–399.

gist came to the aid of the engineer in overcoming one of the greatest barriers to underground travel.

The extreme length of the tunnel tubes, each with a 20-foot roadway "providing for two lines of traffic in the same direction in each tube with an estimated total capacity of 3,800 vehicles per hour," and the assumption that all traffic would be propelled by gasoline engines presented a problem in ventilation which, "both in character and magnitude, had no precedent."

It was therefore necessary to establish original fundamental data on which to base the ventilation plan, as it was fully realized that the success of the tunnel project was dependent on the ability of the engineers to devise a system of adequate ventilation under all traffic conditions. The problem was studied under three main subdivisions:

1. Amount and composition of exhaust gases from motor vehicles;
2. Physiological effects of exhaust gases from motor vehicles;
3. Method and equipment required to provide adequate ventilation.

The most serious gas thrown out by the gasoline motor is, of course, carbon monoxide. Because of the great length of the tunnel this gas was a problem to Singstad and his fellow engineers whether large or small quantities of it were present. It was found that if the carbon monoxide content were kept within safe limits, other gases would not be present in sufficient amounts to be injurious to health. The researchers, however, were handicapped by the fact that "only a small amount of experiments had been made on engine gases, and these results did not give the information necessary to serve as a basis for the planning of the ventilation of the tunnel." There was nothing for Singstad to do but to conduct a series of experiments to establish the necessary data.

With estimates at hand of traffic capacity and such information as was available on the amount and composition of exhaust gases and their physiological effects, Singstad and his associates were convinced that the method of ventilating railroad tunnels — of blowing fresh air from one portal to the other — was not adaptable to this case.

Such large quantities of air were required that the air velocities would be excessive, causing not only discomfort to the traveling

public but also creating a hazard, particularly in case of fires in the tunnel. Many modifications of such a plan were considered whereby intermediate shafts were introduced and the tunnel was divided into several sections. There were many practical objections to all of these plans, and it was concluded that the only practicable method was to supply the fresh air through an independent duct, feeding the air into the roadway from this main duct at frequent intervals and to withdraw the vitiated air through a similar duct also separated from the tunnel roadway, drawing the air from the roadway through openings at frequent intervals throughout the entire length of the tunnel.

By this method, the longitudinal flow of air in the tunnel would be eliminated, the movement being instead a transverse one from the supply duct toward the exhaust duct. Singstad explains further:

> In a tunnel of circular cross-section with the roadway located at an elevation giving maximum clearance for vehicles, there is space available for ventilating ducts both below and above the roadway, one for the fresh air and the other for the vitiated air.
>
> The power required to move the large quantities of air is an important factor, and it was found economical to divide the tunnel ducts into a number of sections by locating the ventilation equipment in four shafts, two on each side of the river. Navigation requirements did not permit the location of any shafts beyond the pierhead lines, which at the site of the tunnel are about 3,200 feet apart.
>
> In designing the ventilation equipment it was necessary to know the coefficient of friction for the flow of air in the concrete ducts such as planned for the tunnel and the power losses where air is taken from or supplied to a duct. No assurance could be found as to any reliable bases for the existing formulas, and it was deemed necessary to verify them by independent tests on large scale models before accepting them as a basis for the design of the ventilation equipment for a project of this magnitude.

The New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission accordingly entered into a contract with the federal bureau of mines, to conduct these tests. Studies to determine the amount and composition of exhaust gases from motor vehicles were carried out at the bureau of mines experiment station in Pittsburgh. A study of the effects of motor exhaust gases was made at the bureau of mines experiment station at Yale University.

The conclusions drawn from the tests have been given by Singstad:

> When an automobile engine with gasoline as a fuel is running properly, the exhaust contains no substance which is toxic to any appreciable extent other than carbon monoxide. Gasoline engines with cylinders missing or when cold, oversupplied with oil or gasoline, or smoking from any cause, may throw off disagreeable vapors irritating to the eyes and nauseating to some persons.
>
> The physiological effects of carbon monoxide are wholly due to the union of this gas with the hemoglobin. To whatever extent the hemoglobin is so combined, by that amount it is rendered incapable to transport oxygen to the organs and tissues of the body. The combination of carbon monoxide and hemoglobin is a reversible reaction, so that when a person returns to fresh air the carbon monoxide is gradually eliminated. Of all physical signs and tests of carbon monoxide poisoning, headache proved the most definite and reliable. Concentration of gas too weak or periods of exposure too short to induce this sign are to be considered harmless. No one had this symptom to an appreciable degree after a period of one hour in the chamber with 4 parts of carbon monoxide in 10,000 parts of air. With 6 parts the degree of effect, if any, was usually very slight, while with 8 parts there was decided discomfort for some hours, although not enough to interfere with the continuance of efficient work in the laboratory or at the desk. . . .
>
> Based on the investigations, a standard of ventilation was adopted providing for a carbon monoxide content in the tunnel atmosphere not exceeding 4 parts in 10,000 under capacity operation.

Tests were also conducted at the engineering experiment station at the University of Illinois to determine the power required to supply and exhaust the air under the adopted plan of ventilation. With data from the three groups of investigations in hand, it was possible to proceed with designs of the ventilating system.

Before actual construction of the system, it was considered advisable to demonstrate it on a large-scale model of the tunnel. This investigation was carried out under an agreement with the bureau of mines in the bureau's experimental mine at Bruceton, Pennsylvania, part of which was reconstructed for the purpose. There was a miniature tunnel, oval in plan, with a roadway length of 400 feet; it was shut off from the outside air except for a drift connecting it to a ventilation plant.

The results of the tests showed that "the methods of transverse air movement investigated were practicable for tunnel ventilation and that the best method from the standpoint of power saving and safety against fire hazard was the one in which the air is introduced from the duct under the roadway and exhausted through the duct above the ceiling."

The plan of ventilation finally adopted is described thus by Singstad:

> Air is supplied to the tunnel from the fresh air duct located under the roadway. The air is taken off from this duct through flues 10 feet to 15 feet apart, provided with adjustable dampers and leading into continuous expansion chambers located just above the roadway, one on each side. From these chambers, two continuous transverse fresh air streams sweep across the roadway and dilute the exhaust gases. The air then slowly ascends to the ceiling where it is drawn through adjustable openings, located from 10 to 15 feet apart, into the exhaust duct. In the four ventilation buildings are located blower fans connecting through downcast ducts with the fresh air ducts in the tunnel. These fans take air from the fan rooms, the air entering the rooms through large louvred openings in the sides of the buildings. In the same buildings the exhaust fans are located in airtight rooms which are connected through ducts with the exhaust duct in the tunnel. The exhaust fans connect to vertical expanding stacks extending above the roofs of the buildings, through which the vitiated air is expelled to the outside atmosphere. The ventilation ducts in each tube are divided into seven sections by transverse bulkheads, so that the equipment in each building ventilates sections of the tunnel extending from the building to the portal or half-way to the next building except in the case of the entrance downgrade between the land and river buildings in each tube, which is ventilated from the land building alone. Each duct section has three fans, two of them required to be operated at full speed to supply the normal maximum ventilation requirements, the third unit constituting the reserve.
>
> The fans . . . are operated by electric motors through chain drives. The ventilation equipment required about 4,000 horsepower at capacity operation.

The Holland Tunnel was not planned and built without considerable doubt and criticism from certain quarters, and there were those who were unconvinced of its efficacy. The first year of its operation was therefore of greatest interest, and Singstad, as engineer in charge of operations, was called upon to report

the results. Parts of his review are of more than casual interest.[37]

During the first twelve-month period, ending in November, 1928, a total of 8,517,689 vehicles used the tunnel. Of this number nearly 80 per cent were passenger cars. The average daily traffic was 23,372, while the average Sunday and holiday traffic was 36,391. The tunnel took about 43 per cent of the auto traffic crossing the Hudson, a figure far in excess of the estimate made in the plans. There was no shutdown except for a few hours on certain nights when the north tunnel was closed in order to take accurate readings of the distribution of air in the various parts of the tube. There was no serious accident, largely because of rigid enforcement of traffic regulations, brilliant illumination, and prompt handling of stoppages in the tunnel. Nearly 200 fires broke out in vehicles that were going through the tunnel. All fires, however, were extinguished by policemen using chemical fire extinguishers, and without the aid of a special fire-fighting apparatus mounted on an emergency truck. Over 2,000 disabled vehicles were towed out of the tunnel, and a number of arrests were made, summonses and warnings issued.[38]

The real test lay, however, in the performance of the ventilation system. Orders were given to operate at a normal maximum capacity on the first day. About 3,760,000 cubic feet of fresh air per minute was provided. Nearly 52,000 vehicles, of which about 98 per cent were passenger cars, went through the tube. The average carbon monoxide content in both tunnels was .69 part per 10,000 parts of air. The highest was 1.60 parts per 10,000. The permissible standard, previously mentioned, is 4 parts per 10,000 parts of air. The longitudinal air draft caused by vehicular movement at times reached 10 miles per hour. It was found, too, that there was never enough fog or smoke to interfere with safe traffic, and, in fact, the public

[37] Ole Singstad, "A Year's Operating Experience with the Holland Vehicular Tunnel," in *Engineering News-Record,* 101:942–949 (December 27, 1928).

[38] For the technical operation of the tunnel, see also "Method of Operating Holland Vehicular Tunnel," in *Engineering News-Record,* 99:700–702 (November 3, 1927).

and the press proclaimed air conditions were actually better in the tube than in some streets of New York City. The general cleanliness of the tunnel was also remarked by the traveling public and the newspapers.

From a purely financial point of view, as well, the tunnel was a success. Whereas its total cost, not including interest on the investment during construction, was about $48,500,000, profit over operating costs was more than $3,500,000 during the first year, one half going to each state. For the first year the tunnel operated at about one half of estimated capacity. Traffic has been at near capacity since the middle thirties. At capacity operation the net annual earnings are about $7,000,000. The tunnel was fully paid for out of toll charges at the end of 1940, or after it had been in use for thirteen years. This was far beyond the expectations of the legislatures of New York and New Jersey back in 1919.[39]

VI

Further tunneling did not, however, await the success of the New York model. In March, 1925, contracts were let for the construction of the George A. Posey Tunnel between Oakland and Alameda, California, which when completed in 1928 was nearly a mile in total length and some 37 feet in diameter.[40]

The cities of Oakland and Alameda, lying on the eastern shore of San Francisco Bay, have grown in recent times to be, with Berkeley and Richmond to the north, an important industrial center. Alameda, besides having the traffic problems com-

[39] Singstad to the author, October 16, 1946.

[40] For a valuable account of the Holland, George A. Posey, and Detroit-Windsor vehicular tunnels by Ole Singstad, see his "Bau von Unterwassertunneln in den Vereinigten Staaten von Amerika," in *Zeitschrift des Vereines deutscher Ingenieure,* 77:265–270 (March 11, 1933). Competent studies of the Posey Tunnel are S. W. Gibbs, "Construction Methods on Oakland Estuary Tube," in *Engineering News-Record,* 100:100–105 (January 19, 1928); A. R. Baker, "The Oakland-Alameda Estuary Tube," in *Engineering* (London), 130:383–386, 449–451 (September 26, October 10, 1930); "Ventilating the World's Largest Subway," in *Domestic Engineer,* 123:18–21, 38, 40–44 (May 12, 1928); Alvin A. Horwege, "Methods Used in the Construction of Twelve Pre-cast Concrete Segments for the Alameda County, California, Estuary Subway," in American Society of Civil Engineers, *Proceedings,* 53 (2):2675-2692 (December, 1927); and "Methods of Controlling Traffic in the Oakland Estuary Tube," in *Engineering News-Record,* 102:710–712 (May 2, 1929).

mon to all dynamic American communities, was cut off from direct connection with Oakland by an arm of San Francisco Bay known as the San Antonio Estuary. Five miles long with an average width of 1,000 feet and a depth of 30 feet over most of its length, this estuary, while important commercially, presented a problem to vehicular traffic that had been only partly met by four swinging bridges fast becoming obsolete. Delays to motorists became unendurable; and finally the federal government condemned the most westerly of the bridges near the business center of Oakland. This action caused the Alameda County board of supervisors to ask George A. Posey, county engineer, to proceed with a study of the vehicular problem and to work out a solution.

Since the country on either side of the estuary is low and flat, a high-level bridge was considered uneconomical and a tunnel was decided upon. In working out the designs, Posey and his associates adopted the methods, somewhat modified, which had been worked out by Olaf Hoff, Ole Singstad, and others. They decided to build 1,000 feet of tube for the underwater section on the Oakland side, float the twelve units of precast tubes, sink them in place, and cover them under water with tremie cement. The tunnel plans called for two lines of traffic and sidewalks on both sides, thus requiring an unusually efficient system of ventilation; the Holland Tunnel system was adopted in all its important aspects. Ole Singstad, its author, acted as consulting engineer for the Posey Tunnel.

The next important vehicular tunnel, which was the first international tube of its kind, was built between Detroit and Windsor, Ontario, and is generally called the Detroit-Windsor Tunnel. Designed by S. A. Thoresen, another American engineer of Norwegian birth and training, this tunnel, like the one at Oakland, borrowed heavily and wisely from the pioneer work of Hoff and Singstad.

Soren A. Thoresen, an 1896 graduate of the Mechanical Trade School at Porsgrund, studied electrical engineering at the technical institute in Mittweida, Germany, before coming to

the United States in 1903. After working for a time in Minneapolis and later with Westinghouse at Pittsburgh, he found his real opportunity with William Barclay Parsons of New York City. Taking employment in 1905 as a draftsman, Thoresen rose to become, in 1940, a member of the present distinguished firm of Parsons, Klapp, Brinckerhoff, and Douglas, consulting engineers. Although his training was along mechanical and electrical lines, Thoresen has participated ably in many other branches of engineering. While his work as an engineer has thus covered a variety of undertakings—including hydroelectric and defense projects—he also made a successful excursion into the field of tunneling and is therefore linked to our story of transportation.[41]

In the early seventies of the last century the people of Detroit were engaged in a heated debate over the relative merits of a bridge or tunnel to cross the Detroit River to Canada. The struggle became tense when two powerful and interested groups lined up on opposite sides in the battle. The shipping interests favored a tunnel, because of their fear of what bridges might do to the high masts of the ships which plied the river. The railroads, on the other hand, favored bridges. It soon became clear, however, that bridges high enough to clear the masts of ships would require approaches a mile long at either end, and favorable opinion for a tunnel thus gradually made headway.

Chesbrough's failure to tunnel under the Detroit River has already been noted. A second venture in 1879, seeking to link Grosse Isle and the Canadian mainland by a tube, was abandoned because limestone formations made the cost prohibitive. When the Grand Trunk Railway tunnel under the St. Clair River was completed at Port Huron in 1891, another flurry of tunnel excitement swept over Detroit, whose citizens feared that shipping might be diverted to Port Huron. In the meantime several renewed attempts to push a bridge project through failed as miserably as the first tunnels. Finally, the remarkable

[41] *Norwegian-American Technical Journal,* vol. 11, no. 2, p. 7 (December, 1938); Wong, *Norske utvandrere,* 73; and information furnished by Thoresen in an interview, May, 1941.

success of the Michigan Central project settled the question of tunnel versus bridge in favor of the former, and when automobile traffic became heavy, a vehicular tunnel under the Detroit River was agreed upon.[42]

Formally opened on November 1, 1930, the Detroit-Windsor Tunnel met a serious need in motor traffic between the two cities. Total crossings both ways reported in 1929 were 17,000,000 passengers and 2,066,000 motor vehicles. Up to 1929 two ferry systems, located about two and a half miles apart, had to carry business and pleasure traffic, a strain increasingly too great for that type of service. The new tunnel, 5,137 feet in length between portals, begins, on the American side, only a few hundred feet from the center of Detroit's financial and shopping district. At the Canadian end the entrance is located in the heart of Windsor's business center. Two and a half years under construction, the tunnel's underwater section of over half a mile was built in sections on shore; these were towed into position, sunk, and concreted after the manner of Hoff's earlier tunnel. The shield-driven sections at both shore ends are about a quarter of a mile long, and the rest, built by the cut-and-cover method, is over a quarter of a mile in length. The roadway, which provides one lane of traffic each way as well as patrol sidewalks, is ventilated in the Holland Tunnel tradition.[43]

While similar to earlier tunnels, the Detroit-Windsor tube nevertheless was novel in several respects. Not least unusual was the financing method used. Late in 1926, Thoresen writes, a man entered the New York offices of Parsons, Klapp, Brinckerhoff, and Douglas, where Thoresen was employed. The visitor put forward the idea of a tunnel under the Detroit River, a project which he thought would be profitable as well as feasible

[42] "Detroit and Canada Vehicular Tunnel," in *Canadian Engineer,* 60:11–15, 53 (April 21, 1931).

[43] "The Detroit-Windsor Tunnel," in *Engineering* (London), 130:605–609, 667–669, 702–705 (November 14, 28, and December 5, 1930); S. A. Thoresen, "Construction of Detroit-Canada Tunnel," in *Canadian Engineer,* 56:257–260. (February 26, 1929); "Detroit and Canada Vehicular Tunnel," in *Canadian Engineer,* 60:11–15, 53; "The Detroit-Canada Vehicular Tunnel," in *Engineering News-Record,* 103:600–606 (October 17, 1929); and S. A. Thoresen, "Constructing the Detroit-Windsor Tunnel," in *Civil Engineering,* 1:613–618 (April, 1931).

from a technical point of view. The tunnel, he said, would be financed by private capital. This promoter, a captain in the Salvation Army, proved to be something more than a visionary. A group of Detroit bankers organized the Guardian Detroit Company, which, assisted by New York and Chicago banking houses, took over the financing of the tunnel and engaged Parsons, Klapp *et al.* as engineers of design and construction. To Thoresen went the responsibility of design; Singstad acted as consulting engineer for the whole tunnel and was responsible for the plan of its ventilation system.[44]

As an international artery of travel the Detroit-Windsor Tunnel presented an unusual problem in traffic regulation. Theoretically it can handle 1,000 vehicles per hour on each of its two lanes, but capacity is regulated in fact by the speed with which customs and immigration officials finish their duties at either end. At the two terminal plazas are facilities for inspection, eight lanes on the American side and ten on the Canadian side being kept busy when traffic is at a maximum. Lights placed on the pavement help customs officials on the American side to detect contraband. Bus passengers are discharged at the terminals and are admitted to the streets after passing a routine inspection.

In the shield-driven part of the tunnel, the distinguishing feature is that for the primary lining structural steel was used instead of cast iron, which had been commonly employed in the past. Greater economy, lightness, ease of erection, and strength were the qualities mentioned in defense of this choice.[45] It should be added that the steel lining was planned by Thoresen.

Several other novel features characterized construction at

[44] Thoresen, in *Civil Engineering*, 1:613–618.

[45] S. A. Thoresen, "Tunnel Lining of Welded Steel," in *Iron Age*, 125:985–989 (April 3, 1930). The question of steel versus cast iron for tunnel lining is a highly controversial one, with respect both to merit and economy. The chief objection made to steel lining is the difficulty — and expense — of making it watertight in places like New York, where this precaution is imperative. The tunnel at Detroit was cut through generally impervious clay which, but for sand pockets, is nearly ideal material for tunneling; as a consequence it was not designed to be absolutely watertight. The only other tunnel built of structural steel without provisions for watertightening is the one under Boston harbor, where ground conditions are similar to those at Detroit.

Detroit. The junction between the shield-driven section and the subaqueous tube was effected without sinking a shaft at that point. The shield was driven into a bell-shaped enlargement of the river tube near the shore. The operation was performed under a clay blanket dumped in advance, the shield being pushed blindly through the blanket.[46] In laying the giant steel tube sections—each measuring about 250 feet in length—which form the river section of the tunnel, sand was first placed in the bottom of the trench at a correct grade by use of a specially designed leveling device. Sand was lowered into the trench by means of clamshell buckets.[47] All in all, the Detroit-Windsor Tunnel, in design and construction, was no mere imitation.

On September 10, 1933, two tunnels—one for vehicles and another, about half a mile distant, for pedestrians and cyclists—were opened to traffic under the Scheldt River at Antwerp, Belgium. Behind this event lies an interesting story of American collaboration and the eastward movement of immigrant skills. In the spring of 1930, M. Frankinoul, a prominent Belgian contractor, visited the United States in anticipation of the Antwerp undertaking. The contractors were responsible for plans, estimates, and bids, as well as for construction. The only tunnel work in progress in this country at the time was at Detroit, where Frankinoul studied construction techniques and decided to employ the Parsons firm as consultants. But before returning to his homeland he made further inquiries and as a consequence asked Singstad to serve in a consulting capacity. In the completed shield-driven tunnels at Antwerp, American precedents were followed throughout, except for the escalators and elevators serving the pedestrian tube. Cast-iron linings similar to those in New York were adopted, on Singstad's recommendation. Singstad designed not only this lining in all details but also the tunnel shield, and he was wholly responsible for the ventilation system and the equipment design. Thoresen,

[46] Thoresen, in *Canadian Engineer,* 56:257–260.
[47] Thoresen, in *Civil Engineering,* 1:613–618.

representing his firm, also participated as an active consultant and has given an interesting record of the project. Both Americans were decorated by King Albert for their services.[48]

In the meantime traffic across the Hudson between New York City and New Jersey had continued to increase rapidly. The Port of New York Authority, established in 1921 by the states of New York and New Jersey to promote the commercial development of the New York port, with special regard to improving terminal and transportation facilities,[49] was faced with the fact that all vehicles crossing the Hudson in the vicinity of New York City were borne by the George Washington Bridge (completed in 1931), the Holland Tunnel, and nineteen ferries. Traffic had risen from 5,000,000 vehicles in 1915 to 31,500,000 in 1936 — an increase of over 500 per cent in twenty-one years. A further increase to 40,000,000 was anticipated by 1941.[50] The Holland Tunnel and Washington Bridge left the large mid-town section of Manhattan unprovided for. The result was that the Port Authority planned what is called the Lincoln Tunnel to link New Jersey with the central Manhattan business district and to form part of a future through highway route to Long Island.[51]

The Lincoln Tunnel followed the Holland tube in its basic plan. O. H. Ammann, the Port Authority's engineering director, was responsible for designing and all other work, but Singstad, chief consulting engineer on tunnels for the Port Authority, was also chief consultant on this enormous project, the southern tube of which measured 8,215 feet between portals and called for exceptional skill in construction.[52]

[48] Ole Singstad, "Vehicular and Pedestrian Tunnels at Antwerp," in *Civil Engineering,* 4:1–5 (January, 1934); and S. A. Thoresen, "Shield-driven Tunnels near Completion under the Schelde at Antwerp," in *Engineering News-Record,* 110:827–832 (June 29, 1933).

[49] "The Port of New York Authority," in *Engineer* (London), 162:2–4 (July 3, 1936).

[50] O. H. Ammann, "Planning the Lincoln Tunnel under the Hudson," in *Civil Engineering,* 7:387–391 (June, 1937).

[51] "New Road under the Hudson," in *Engineering News-Record,* 118:901–907 (June 17, 1937).

[52] Two excellent accounts of this tunnel are "The Lincoln Vehicular Tunnel," in *Engineer* (London), 164:276–279, 284, 302–305, 310 (September 10 and 17, 1937);

Almost directly across from the Lincoln Tunnel, connecting Manhattan and Queens, the Queens Midtown Tunnel carries vehicles under the East River, relieving a great traffic strain that had existed for many years. Prior to the construction of this tunnel, the Queensborough Bridge was the only crossing on the East River for a stretch of over 5 miles between Triborough Bridge to the north and Williamsburg Bridge on the south. The new tunnel not only carries traffic between Queens and Manhattan, but also serves as an important link in a highway system in Greater New York which furnishes a "direct connection between midtown Manhattan and Queens, Brooklyn and the routes that lead to the communities, parks and resorts that lie farther out on Long Island, while via the proposed Midtown Manhattan Underpass the system will be extended to the west side of Manhattan, and by way of the Lincoln Tunnel across the Hudson River to the mainland." [53]

The Queens Tunnel, conceived at an early date, was only slowly realized; but the mounting volume of traffic, the inadequacy of existing crossings, and the pressure of citizen groups all served to hasten its construction. After numerous preliminary steps, largely negated by the depression that followed 1929, the New York State legislature created in the Queens Midtown Tunnel Authority "a public benefit corporation empowered to plan and construct the Queens Midtown Tunnel as a self-supporting and self-liquidating project." No funds were provided; in 1935 the Queens Midtown Tunnel Authority asked the Public Works Administration for assistance, and at the same time received a loan from the city for making preliminary plans and studies. Finally in January, 1936, a P.W.A. loan and grant of $58,365,000 was approved, $47,130,000 of which was in the form of a loan. During the same month the name of the new body was changed to the New York City Tunnel Authority, which still exists. "The obligations of the Au-

and "The Lincoln Vehicular Tunnel, New York," in *Engineering* (London), 145:375-377, 435–437 (April 8 and 22, 1938).

[53] Ole Singstad, "The Planning and Construction of the Queens Midtown Tunnel," in *Municipal Engineers Journal*, no. 3, p. 114 (New York, 1938).

thority are not a debt of the State or City of New York, and the Queens Midtown Tunnel will be operated and its cost amortized out of revenues from tolls, without any expense to taxpayers. When all the liabilities of the Authority have been met, its corporate existence will terminate, and all its rights and properties pass to the City of New York."[54]

Singstad, as chief engineer for the New York Tunnel Authority, had charge of the design and construction of the Queens Midtown Tunnel. Preliminary plans were altered, and after considerable delay caused by politicians, the work of tunneling was begun. Completed in 1940, this tunnel, the most difficult to construct and therefore the most costly, resembles both the Holland and Lincoln tunnels. The cast-iron sections measure in diameter slightly more than those in the Holland Tunnel, thus giving a wider roadway. Improved lighting, larger air ducts, better use of fans, and general progress in details characterize the newer project in a comparison with the Holland tunnel—but the pattern is the same. Composed of two double-lane tubes, the tunnel measures over 6,000 feet in length and was cut through extremely unfavorable ground. The cost was about $55,000,000, which represented a saving of millions below estimate; it was completed in less than scheduled time.[55]

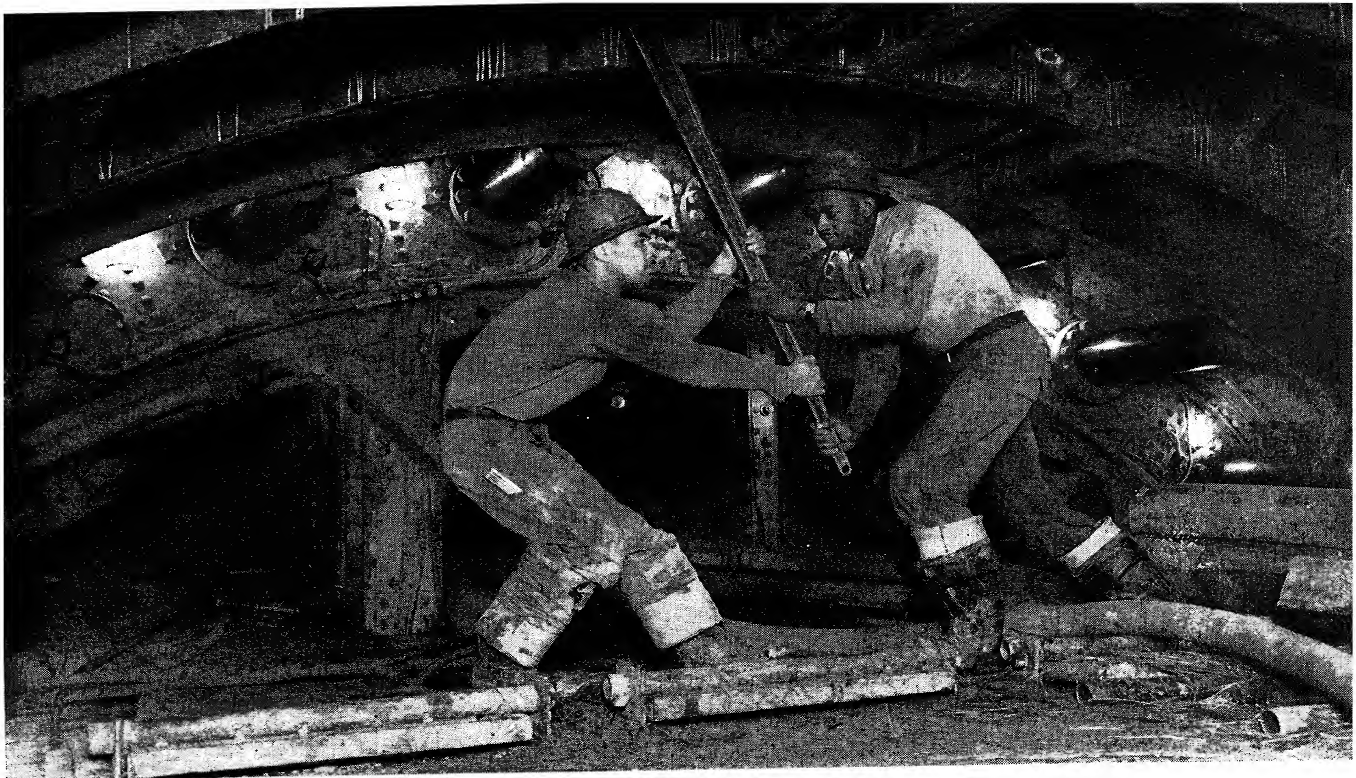
Singstad writes, discussing the completed Queens Midtown Tunnel: "Extended research is no longer necessary in planning and designing tunnels for highway traffic, and, with proper coordination of contracts, such projects can be completed in a practical minimum of time. The operation of existing highway tunnels will continue to provide data for improvements in design which will add to the safety, utility, and economical operation of future tunnels."[56] The pioneer period is past.

But the story of Singstad's career did not end with this project. Under construction at the time of Pearl Harbor was a

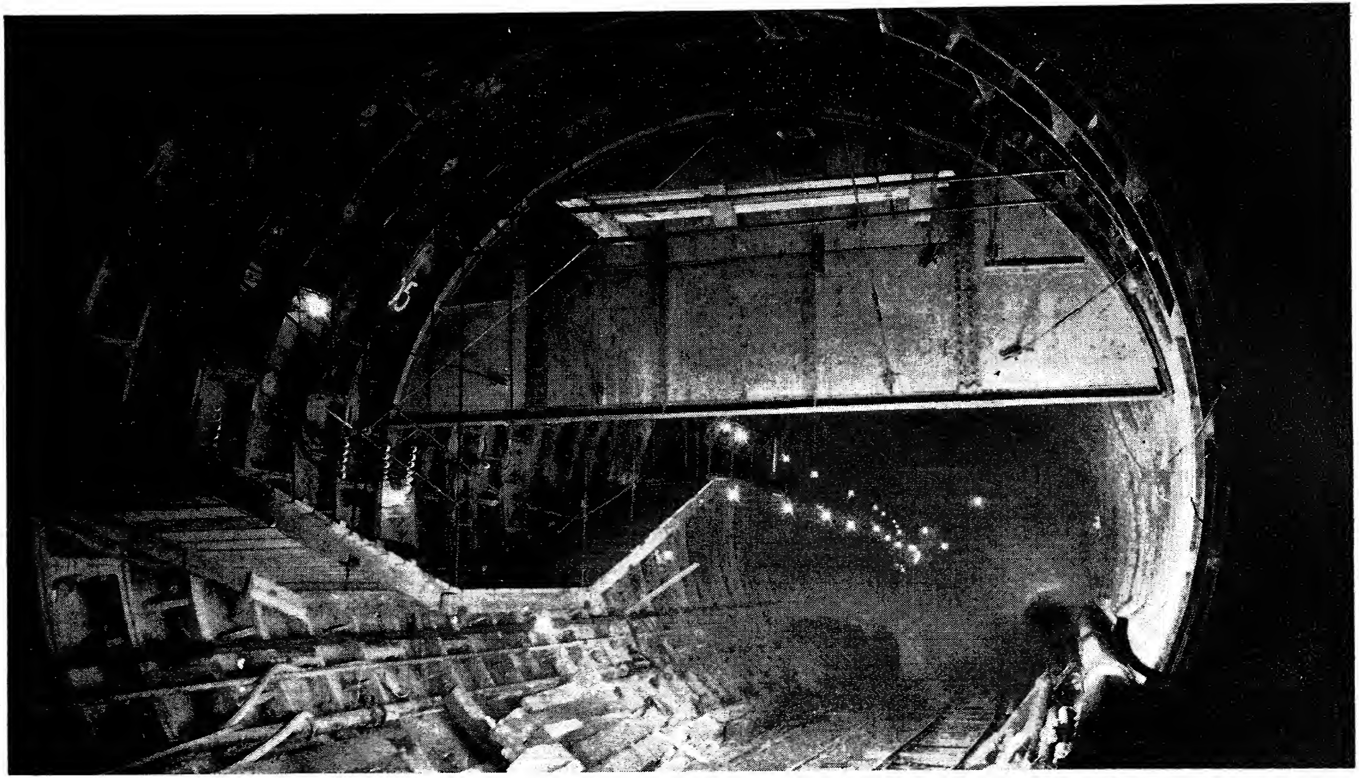
[54] Singstad, in *Municipal Engineers Journal*, 117.

[55] Singstad, in *Municipal Engineers Journal*, 119–133. Since this section was written, a more comprehensive account has come from Singstad's pen, "The Queens Midtown Tunnel," in American Society of Civil Engineers, *Transactions*, 109:679–762 (1944).

[56] American Society of Civil Engineers, *Proceedings*, 69:396 (March, 1943).



Sandhogs Tightening Bolts, Queens Midtown Tunnel



Safety Screen and Emergency Runway, Queens Midtown Tunnel

$75,000,000 undertaking to be known as the Brooklyn-Battery Tunnel, which the New York City Tunnel Authority is driving from Hamilton Avenue in Brooklyn to the Battery. When completed it will serve as a link in a by-pass route around the congestion encountered on the way to Manhattan. The Battery tunnel had a spectacular beginning because of a controversy that resulted in 1939 from the sudden proposal by certain interests to substitute a bridge. The fight raged for several months and was finally resolved by the war department, which favored the tunnel. The two tubes of this tunnel, when shut down because of wartime problems, each had advanced a distance of 2,800 feet from the Manhattan shore and a maximum of 1,200 feet from the Brooklyn construction shaft. The Brooklyn-Battery Tunnel, which will perhaps be completed in 1949, will be the longest vehicular tunnel in the country, measuring some 9,117 feet in length.

A proposed Narrows tunnel connecting Brooklyn and Staten Island will in all probability be the next subaqueous project of importance in New York. It will provide for two lanes of traffic in either direction, will be operated on a toll basis, and will cost about $73,500,000. The Narrows tunnel is expected to stimulate residential and commercial development on Staten Island, whose growth has been retarded by lack of physical transportation connections except for bridges to New Jersey. It will serve, too, to by-pass through travel between the South and West and New England around the congested sections of New York City and will complete an outer belt loop. The tubes may be constructed by either the trench or the shield-and-compressed air method in the Narrows undercrossing; the land section connecting to the portal in Brooklyn will consist of two cast-iron lined tubes constructed by the shield technique; and the land section on Staten Island will resemble the opposite end except for a short section of cut-and-cover construction.[57]

Singstad, baldish, short, and vigorous, had thirty-five years

[57] See Singstad's *Final Report of New York City Tunnel Authority on Proposed Narrows Highway Tunnel between the Boroughs of Brooklyn and Richmond* (New York, 1945).

of public service before retiring in 1945 to his own private practice. He has had the distinction and pleasure of seeing his work properly appraised and himself recognized as the greatest tunnel authority in the world. At the time of the opening of the Holland Tunnel the *New York Times* stated editorially: "To Ole Singstad, Holland's Designing Engineer, fell the task of finishing an undertaking that will rank with such engineering monuments as the Panama Canal. . . . Technical history was written when the ventilating apparatus was designed."[58] Engineers and scientists have since acknowledged Singstad's preeminence in the field that he has made a lifelong specialty, and institutions like New York University and Stevens Institute of Technology have echoed this acclaim by conferring honorary doctoral degrees, while mentioning also his "daring vision and irrepressible action," his resourcefulness and skill.[59]

VII

To many Norwegian Americans living in New York City or in one of its near-by suburbs, Sverre Dahm's name is still a familiar one. The reason is not far to seek. Though he neither sought nor received great publicity, Dahm is remembered as one of the leading engineers associated with the construction of the now excellent subway network in Greater New York, from its beginnings in 1900 to his death in 1932. Over its tracks, millions regularly travel at great speed to and from their work. Dahm supervised the design of the various branches of the B.M.T. and I.R.T. roads and of the entire New York City subway system still under construction in the 1930's. Subway construction, though it involves most of the engineering sciences, has many features in common with tunneling, and Dahm's name therefore belongs properly beside those of Hoff and Singstad.

England was the birthplace of the subway as well as of the

[58] November 11, 1927.

[59] It should be mentioned that Singstad was consulting engineer on the tunnel approaches to the George Washington Bridge, the Penn-Lincoln Vehicular Tunnel at Pittsburgh, and similar projects. He has also lectured on foundation engineering and similar subjects at Harvard and New York universities.

shield-driven tunnel; the first underground system of tracks was one designed in 1860 to connect some twelve ordinary railway stations in London. No sooner was this project completed than regular underground railways were planned; the earliest of the "tuppenny tubes" was begun in 1886. The Paris Metropolitaine was authorized in 1898 and its first section opened three years later.

The history of New York's subways began in a novel manner when Alfred Ely Beach, an engineer-editor, invented a shield and proposed a tunnel, operated by pneumatic power, to carry such items as mail, merchandise — and possibly passengers — in the Manhattan area. He actually tunneled through the earth under lower Broadway as early as 1868–70 and an experimental section of about a hundred yards was in fact operated, but the project was abandoned because of the development of elevated lines, political opposition, and the fear current among engineers of the time that tunnels bored beneath narrow streets lined with great buildings involved too hazardous an undertaking.[60] Thus the first contract for a subway system was let as late as 1900, the contractor agreeing to build 21 miles running from City Hall northward by two routes to the Bronx. William Barclay Parsons was chief engineer of the project.[61] Dahm, as assistant designing engineer, planned much of this line, and before it was completed in 1904, he had already begun a second unit.

Sverre Dahm's career is in several respects unique. With him the significant history of Norwegian engineers in New York really began. Not entirely inexperienced in railroad work, Dahm had built a stretch of the Vestbanen in southern Norway before coming to America. He sailed from the Old World with his close friend Gunvald Aus, with whom he had studied at the Munich Polytechnicum, and together they obtained work with Theodore Cooper and Bernt Berger some time after their arrival in 1883. This unusual friendship, which persisted through

[60] An interesting account of this "subway" is in *Scientific American,* vol. 22, no. 10 (March 5, 1870).
[61] Kirby and Laurson, *Modern Civil Engineering,* 180–182.

the years, had a third party added to it later in the person of Kort Berle, with whom Aus was to make history in the development of skyscrapers. Dahm's first experiences in America, however, were with the Delaware Bridge and Union Bridge companies as designer and computer of stresses. His next assignment took him to Panama in 1884, where he mapped the country on the Pacific side of the proposed canal site. Returning the next year to the States, he became bridge engineer with the Long Island Railroad. In 1889 he took charge of the office of a consulting engineer, Albert H. Wolf, in Chicago, and there had an opportunity to participate in skyscraper construction in its infancy. Later in New York he was responsible for the designs of numerous tall office buildings during an association with the Jackson Architectural Iron Works.

Dahm was peculiarly well trained for the work that was to crown his brilliant career. Steel and skyscraper, railroad and tunnel problems were a major part of the difficulties facing a man in charge of subway design. Dahm took employment in 1900 with the board of rapid-transit commissioners. As the administration of subways switched from organization to organization, Dahm served with the public service commission, the transit construction commissioner, the transit commission, and finally the board of transportation. He fully earned the reputation of being the world's foremost subway designer. By 1929, when he resigned, he was the only board engineer in high position who had been connected with New York subway construction from its beginning; he had 800 engineers under his supervision, and directed a yearly budget of some $75,000,000. From 1905 on Dahm had been in charge of the design department, and in 1925 he was appointed deputy chief engineer, in charge of designs, of the board of transportation. Following his retirement, he served as consulting engineer till his death in February, 1932.[62]

[62] So far as the writer is able to determine, Dahm published only one article relative to his work — a summary of tests made of the steel-concrete construction used in building extensions of the New York Rapid Transit Lines; *Beton und Eisen* (Berlin), 2:100 (1904).

An understanding of the nature of Dahm's work and of the responsibility he carried is clear to one who recalls, among other things, that by the end of 1925 subway rapid-transit lines in New York City carried almost 2,000,000,000 passengers, while surface cars carried only half that number. In 1923, whereas there were over 47,000 accidents on surface cars, there were only about 15,000 similar cases on the subway and elevated lines. Underpinning beneath the skyscrapers of lower Manhattan and below the narrow streets was another problem. The buildings had to be left intact and business permitted to continue its normal course during construction. Building foundations were jacked up and then columns or piles about 15 inches in diameter placed under the jacks, the weight of the buildings pushing down one spliced pile upon another deep into the earth. This simple method could not always be used, however, for an intricate maze of gas pipes, steam and water mains, tunnel aqueducts, high- and low-tension wire ducts, submarine cables and pneumatic tubes, sewers, and surface trolley track supports had somehow to be avoided and proper underpinning provided in one ingenious way or another.[63]

During the period of Dahm's service, rapid-transit lines to the value of about $800,000,000 were designed and built and for most of it Dahm himself had charge of the designing features involved. Though he was consulted on every aspect of planning and regarded as final judge in all technical phases, his specialized knowledge of the principles involved in steel and reinforced-concrete design was singled out by engineers as his most valuable asset.[64] He will also be remembered as the author of the steel-bent type of structure used to build subways and as one of the most efficient and loyal employees ever to work for the city of New York.[65]

[63] An excellent account of this and other phases of Dahm's work is provided in an article by Katrine Hvidt Bie, in *Nordisk tidende,* July 8, 1926.

[64] Robert Ridgway and A. I. Raisman, in American Society of Civil Engineers, *Transactions,* 96:1448–1451 (1932).

[65] *New York Times,* February 15, 1932, and *New York Herald Tribune,* February 15, 1932. In addition to the accounts listed above, see *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 9 (July, 1929) and vol. 6, no. 1, p. 10 (April, 1933); Wong, *Norske utvandrere,* 67; and archives of Norwegian-American Technical Society,

VIII

The contributions of Anders Bull during the early years of radio are discussed elsewhere in this volume. But Bull, well past the years in life when the average engineer has done his best work, has also earned an enviable reputation as research engineer with the New York board of transportation, as a result of discoveries that are significant in the subway story. Inventive of mind, with wide interests and a purely scientific approach to problems, Bull has made studies in acoustics, track alignment, reinforced concrete, and earth pressure. Perhaps his most lasting contribution to engineering knowledge has derived from a mechanical system of calculating stresses in statically indeterminate structures, a subject about which he has written and lectured considerably. Using a wire model, he has been able to determine stresses produced by settlement in a multiple-frame structure. Mathematical analysis had been found too extensive and cumbersome for practical use, and previous methods of model analysis based upon Maxwell's law of reciprocal deflections were found impracticable by Bull. His new system avoided both earlier disadvantages and he has demonstrated its accuracy by checking results with values determined mathematically.[66]

Bull moved on to a similar problem in foundation engineering—how to determine the soil pressure distribution along a flexible slab transmitting its load to an elastically yielding ground. Finding comparatively little reliable information on the subject, despite the extensive use of flexible foundation slabs in modern structures, he set about discovering a simple and direct method of determining soil pressure distribution, knowing that such a method was essential in subway work as well as in foundation design. In subways the "bottom slab or 'invert' transmitting the weight of the structure and overlying soil to the ground below, is subjected to an ever varying array

Chicago. There is no really adequate study of the New York subway system; but Gilbert, Wightman, and Saunders, *Subways and Tunnels of New York* (New York, 1912) and Archibald Black, *The Story of Tunnels* (New York, 1927) are useful.

[66] Anders Bull, "Settlement Stresses Found with a Model," in *Civil Engineering*, 7:561–565 (August, 1937). An earlier report is found in numbers 48, 49, and 50 of *Teknisk ukeblad* (Oslo, 1930).

of loading conditions." Bull recently presented to the Franklin Institute the details of two methods approaching the problem in different ways and "meeting all reasonable demands for speed, simplicity and accuracy."[67] The institute was sufficiently impressed to award him the Louis E. Levy medal for "a paper of especial merit" containing material that is "both theoretical and experimental, original with the author and in a field of fundamental importance." Of Bull's methods of determining pressure, the institute said that his approach "enables the engineer to predict the resulting earth pressures along a foundation, with a minimum of calculation and with a maximum of certainty."[68]

IX

August Gundersen, now manager of Høyer Ellefsen, Norway's largest contracting firm, was Olaf Hoff's first assistant during the construction of the Detroit River Tunnel. Then only twenty-seven years old, he was chief engineer for the firm Butler Brothers-Hoff Company, which had the tunnel contract. With the Detroit job completed, however, Gundersen returned to Norway, thus depriving this country of a promising engineer.[69] Hoff's confidence in Norwegian engineers is further demonstrated by the fact that his first assistant for the Harlem River Tunnel was Guttorm Miller, now chief engineer of the A. I. Dupuis Company of Detroit. Miller, a graduate of Christiania's Technical College, was construction engineer for the Pennsylvania Railroad tunnels under the East River, New York City, and the Michigan Central Tunnel under the Detroit River. He was once underpinning engineer for the New York subways and is now an expert on hydroelectric construction and docks.[70]

[67] Anders Bull, "Soil Pressure Distribution along Flexible Foundations," in Franklin Institute, *Journal,* 233:559–580 (June, 1942).

[68] *Nordisk tidende,* May 13, 1943. Bull has also contributed an article of special interest to the tunnel story: "Stresses in the Linings of Shield Driven Tunnels," in American Society of Civil Engineers, *Proceedings,* 70 (2):1363 f. (1944). On January 31, 1944, Bull retired from the board of transportation, having reached the age limit of seventy.

[69] *Skandinaven,* December 14, 1937.

[70] Archives of Norwegian-American Technical Society, Chicago.

Gundersen and Miller may be linked with Hoff's work, while Hans Rude Jacobsen is associated historically with Singstad. Born in Drammen in 1876 and a graduate of Christiania's Technical College, Jacobsen is a genial dean among New York's Norwegian engineers and has been active in tunnel work over a long period, chiefly in connection with the city's subway system. Associated first with the Rapid Transit Subway Construction Company in 1902, when it began subway work, in 1904 he was made engineer in charge of the eastern part of the Belmont Tunnel under the East River and its extension in Long Island City. In 1917–18 he was consultant for two tunnels under construction on Long Island, until he joined the army as captain of engineers and was engaged by General G. W. Goethals to make reports on tunnels in New York and Seattle. Later employed by the city of New York as engineer in charge of caisson and triangulation work for the Narrows railroad tunnel, he did significant work from 1922 to 1934 on subway tunnels. When he retired from the board of transportation, he was appointed by the federal government to be supervising engineer of the Lincoln Tunnel. After 1936 he was in charge of construction on the Queens Midtown Tunnel at Long Island City.[71]

Erling Owre, a graduate of Trondhjem's Technical College, has worked closely with Singstad as architect with the New York City Tunnel Authority. He has designed the architectural features of the ventilation buildings and the portal and open-approach embellishment of more vehicular tunnels than any other man; his projects include the Holland, Queens Midtown, Brooklyn-Battery and the proposed Narrows tunnels.[72]

Others have helped to make American tunnel and subway history. Emil Bie, like Miller a graduate of Christiania's Technical College in 1900, has served with the Interborough Rapid Transit Railway Company and the New York State Barge Canal Office, and was associated with the design of the Narrows railroad tunnel. At present he is engaged in the design and

[71] Magnus Bjørndal, in *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 11 (November, 1935).

[72] Alstad, *Trondhjemsteknikernes matrikel,* 165; Alstad, *Tillegg,* 46.

construction of new subway lines at the board of transportation. He has contributed to engineering knowledge by his researches in indeterminate structures, soil pressure, and transit line operation. His most outstanding contribution is a new theory for the calculation of soil pressure as it affects tunnels and subways. In November, 1923, he presented a paper on this subject before the Brooklyn Engineers' Club, winning the Alfred T. White prize of the year for his originality.[73] He won considerable recognition, together with Alfred Varley Sims, brother of Admiral Sims, as a result of their scheme for air-raid shelters in New York's subways.[74] They proposed to build subway stations in outlying areas of Greater New York; later these would be transformed into finished subway stations and tunnels would be driven linking them together. The Sims sand slab was recommended for use as an under-street covering for the station. A model has been demonstrated; it was based on Bies's study of soil pressure.[75]

An electrical and mechanical engineer of note who died recently was Alf Hjort, chief engineer of the George H. Flinn Corporation. Hjort was born in Christiania in 1877 and educated at the Hanover Polytechnicum. After practicing in Berlin and London, he came to the United States in 1903 as electrical engineer for S. Pearson and Son of England, in the construction of the Pennsylvania Railroad tunnel under the East River. After 1909 he was engineer for the Degnon Contracting Company on the Catskill water-supply project, and in 1914 he joined the Flinn Corporation, engineers and contractors. Other projects in which he participated prominently were the Manhattan, Brooklyn, Queens, and Bronx subways, the Montague and Clark streets tunnels, the Holland and Brooklyn-Battery vehicular tunnels, the Bayonne dry dock for the navy, the Liberty Tunnel in Pittsburgh, the International Bridge over

[73] "Arching Effect in Soil," in Brooklyn Engineers' Club, *Proceedings*, no. 190, p. 5–54 (January, 1924).

[74] Magnus Bjørndal, in *Norwegian-American Technical Journal*, vol. 8, no. 1, p. 12, 23.

[75] *Queens Civic News*, April 10, 1941; Emil Bie, "Subway Shelters," in *Norwegian-American Technical Journal*, vol. 14, no. 1, p. 3–5 (May, 1942).

the St. Lawrence River at Cornwall, Canada, and highway and bridge construction for the Westchester County parkway system. Hjort died in December, 1944.[76]

Berge B. Furre, as a draftsman with the Rapid Transit Subway Construction Company, was involved in the building of New York's first subway; later, with the board of transportation, he advanced to the position of designing engineer in the planning division in charge of general designs and the layout of new rapid-transit lines in the 1920's and early 1930's.[77]

Bjørgulf Haukelid, a graduate of Christiania's Technical College in the early years of the present century, also served as subway designer under Dahm. Shortly after the end of World War I he returned to Norway. His daughter is the film star Sigrid Guri, who was born in Brooklyn.

Tollef B. Mønniche worked on the Panama Canal as first assistant in 1907 to Professor David Molitors and designing engineer of the emergency dams on both sides of Gatun Lake. When Molitors left to accept a position at Cornell University, his place as chief of the project was taken by Mønniche. A graduate of the War Academy in Norway and of the technical institute at Dresden, Mønniche had come to America in 1901 and had been employed by the Pennsylvania and Virginian railroads before going to Panama.[78]

Thus in the history of tunneling in America, the development of the trench-and-tremie method at Detroit, in which Hoff figured prominently, added a new and revolutionary type of construction to the familiar shield method. With the advent of the automobile, itself of untold significance in our economic and social life, a new kind of underwater tunnel, adapted to the peculiar needs of the gasoline motor, came into being in the twenties and thirties of the present century. A great engineering feat in any aspect, the vehicular tunnel owes its remarkable

[76] *Nordisk tidende,* December 21, 1944; *New York Times,* December 14, 1944; *Engineering News-Record,* 133:799 (December 21, 1944).

[77] Wong, *Norske utvandrere,* 69; materials in archives of Norwegian-American Technical Society, Chicago.

[78] *Minneapolis tidende,* May 3, 1917, and August 15, 1919; *Nordmanns-forbundet,* 7:57 (1914), and 28:343 (1935).

success to the method of ventilation developed by Singstad. S. A. Thoresen made his greatest single contribution in the Detroit-Windsor Tunnel, and proved that steel could be used as a tube lining. Sverre Dahm might with justice be termed the technical father of New York's subway network. And numerous other engineers from Norway, though less familiar to the general public, have contributed to the tunnel story with skills potentially as great as those of the men in prominent positions. The result of their combined efforts is nothing less than a revolution in tunneling.

BUILDING TO THE SKIES

THE American skyscraper is a source of unfailing comment by foreign visitor and American alike. Though — as was the case with the Gothic cathedral — the skyscraper is sometimes termed crude and naïve in conception, it has generally been hailed as a dynamic form embodying the restless energy and initiative of the New World. "In the skyscraper," Alfred C. Bossom, a well-known British architect, has said, "America has invented and developed a wholly new and revolutionary form and type of building that is absolutely and characteristically her own. . . . These mighty structures proclaim the daring, the inventiveness, the self-confident power of their creators." According to the same writer, twentieth-century America, "susceptible to size, eager for novelty, spurred on by a conquering quasi-Elizabethan vitality and groping for expression, found it, to its immense satisfaction and stimulus, in the skyscraper.... The stamp of the pioneer was on it from the first."[1]

Bossom's views have been generally accepted by discerning Americans. Few indeed who have traveled from city to city in the United States will deny that the skyscraper occupies the same dominant position once held — and in many cases still held — by the cathedral in the cities of Europe. To the traveler from abroad the parallel is at once apparent.

It would be wrong to assume, however, that the skyscraper was aesthetically inspired or primarily the creation of a new school of architecture. It was rather the product of the American

[1] *Building to the Skies, the Romance of the Skyscrapers,* 9, 14 (London, 1934). Bossom expresses himself similarly in the *New York Herald Tribune,* July 22, 1928. The skyscraper, he says, is "the one new thing in the architectural world, and it typifies America the world over."

economic revolution and as much a part of modern business as banking and the factory system. Built by engineers trained in bridge construction, the skyscraper developed from this technique and grew naturally with the growth of America itself. Among the engineers who saw the new structure originate and assisted in its growth were several Norwegians, who thus had a peculiarly vital part in one of the most significant chapters in recent American history.

I

No understanding of the part played by these men is possible without a fuller history of the skyscraper. While associated in the popular mind with lower Manhattan and the loop district of Chicago, the tall office building is found in every American city of any size and volume of business, and the explanation is the same in all places. After due allowances are made for an understandable competition between cities and firms, and for a national fondness for display, size, and great financial outlay — even of recklessness and daring — it is found that the skyscraper came into being as a result of certain changes in American commercial life. Toward the end of the nineteenth century efforts were made to combine various business units both vertically and horizontally, thus bringing vast segments of our economic life under unified control and common ownership. With the success of these attempts, "The association between businessmen and their lawyers, manufacturers and their banks, merchants and their creditors, became so close and so continuous that neither letters nor the telegraph nor even the newfangled telephone were competent to handle it."[2] In other words, the skyscraper was one with giant mergers, the concentration of business, and the specialization and increasing interdependence of the various units of the industrial and commercial world. It was the inevitable structural result of New World economic conditions.

As business tended to concentrate in certain sections of our cities, a demand arose for offices on a particular street or group

[2] "The Skyscraper," in *Fortune*, 2: 86 (December, 1930).

of streets in these areas, and with this demand for office space went a corresponding increase in land values in the chosen districts. Rising land values forced buildings higher and higher; it therefore became necessary to build so that the financial return would be "commensurate with the investment. The reason for a building is to supply floor area and the more floors there are the greater the rentable floor area from which the income is obtained." [3] The only deterrent to height is the fact that each added story costs more to build than the preceding one. The matter thus resolved itself into the familiar problem of increasing costs. Just where the economic height or point of optimum financial return is reached is determined by many factors, chief of which is the cost of land. Assuming land values at $200 per square foot, Clark and Kingston in 1930 declared 63 stories to be the point of greatest return on the office building investment.[4] Changes in land values and in costs of materials and labor naturally prevent any such figure from becoming a static one; it changes with the fluctuations of modern life. One authority went on record in 1930 with the following words, "As an engineer I know that tall buildings can be safely built to a height of 2000 ft. . . . but whether such buildings would pay on the investment . . . is a matter that must be passed upon by others." [5]

Since the trend in office buildings has been skyward, the major question involved was whether or not skyscrapers could be made to stand up, despite their great height, and thus not endanger the lives of thousands of people. This was essentially an engineering problem and "the skyscraper has been shaped and developed by practical . . . necessity." [6] There was no weight of tradition to hold back the structural engineer. Closer

[3] George E. J. Pistor, *The Art and the Economics of Skyscrapers,* a speech delivered July 18, 1930, in London, and printed in pamphlet form.

[4] W. C. Clark and J. L. Kingston, *The Skyscraper, a Study in the Economic Height of Modern Office Buildings,* 150 (New York and Cleveland, 1930).

[5] Pistor, *The Art and Economics of Skyscrapers,* 3.

[6] Claude Bragdon, "Skyscrapers," in *American Mercury,* 22:289 (March, 1931). In fairness to the present-day architect it should be stated that his training now includes a thorough study of engineering problems and that he is now fully aware of the basic nature of his task.

than the architect to the industrial civilization that he helped to create, he was ready to push buildings into the sky without regard to the past, and he waited only for materials strong enough for the skyscraper's frame and for foundations capable of bearing the tremendous weight of the skeleton. Fortunately for him, the introduction of structural steel and of the modern foundation, both of which had already been used in bridge construction, kept pace with the commercial centralization creating the congestion that in turn necessitated the tall office building.

On the other hand, the architect, who until late in the nineteenth century worked traditionally with such materials as brick, stone, and wood and exercised his talents on such subjects as churches, houses, colleges, theaters, and — more recently — civic buildings and banks, was unprepared to meet the new challenge that confronted him almost overnight. He "misconceived his problem, which is not to *adorn* the necessitous engineering structure, nor to make a translation of it into this or that dead architectural style, but to dramatize it."[7] What the architect did at first was to try to conceal the building's height and structural form. He used cornices and attempted to make the walls give the appearance of supporting the structure. He tried to make office buildings look like Roman palaces and, later, like Gothic churches. This eclectic tendency finally went to such lengths that some architects, notably Louis H. Sullivan, asked, "when native instinct and sensibility shall govern the exercise of our beloved art; when the known law, the respected law, shall be that form ever follows function; when our architects shall cease struggling and prattling handcuffed and vainglorious in the asylum of a foreign school?"[8] While other architects continued to speak in a foreign language with a slight American accent, Sullivan pioneered by demonstrating that a skyscraper "need not and should not be made to look as though the walls were of solid masonry. . . . He emphasized and 'opti-

[7] Bragdon, in *American Mercury,* 22:290.

[8] Louis H. Sullivan, "The Tall Office Building Artistically Considered," in *Western Architect,* 31:3–11 (January, 1922).

cally' increased the building's height by means of long, unbroken vertical lines, forever putting an end to the ridiculous practice of piling the classic orders on top of one another like a house of cards."[9]

In summing up this development, an American historian of architecture writes, "Civil engineers had run up to unbelievable heights skeletons of steel . . . but the architect . . . doggedly and blindly refused to see in this wonderful new thing a glorious opportunity. He feared the engineers while bearing gifts." And again: "It is futile and to my notion aesthetically wrong to condemn or oppose the skyscraper. . . . In its train has come the most brilliant era of structural engineering that the world has ever known."[10]

Briefly considered, the skyscraper is composed of an elongated steel skeleton, or frame, a "system of riveted-together vertical and horizontal members insuring strength, lightness, rigidity, stability . . . being, in effect, a truss stood on end."[11] Supporting this skeleton is a foundation ingeniously built on hardpan or solid rock. Inside the building—"the very piston of the machine"—is the speedy, safe passenger elevator. Around the steel frame is a veneer material which, unlike the walls of the past, has no supporting function but is decorative and protects against the weather.

Contrary to popular notions on the subject, the skyscraper originated in the West, the first of its kind rising out of the swamp that is now Chicago. It was there, too, that the modern foundation, without which the great structures of today would be impossible, was developed to overcome the uncertain support of Chicago's mud and fill. And like so many other features of modern life, the tall office building is of recent origin. It was in the 1880's that the foundation problem was solved, permitting Chicago temporarily to lift its skyline higher than its great rival in the East. Charles Sooysmith, an engineer-contractor, was first to sink the necessary piers to bedrock. The first patent

[9] Bragdon, in *American Mercury*, 22:290.
[10] Tallmadge, *Architecture in America*, 252, 296.
[11] Bragdon, in *American Mercury*, 22:289.

for a steel frame building was also taken out in the eighties by a westerner, L. S. Buffington. Bossom says that Buffington was a Minneapolis architect and that his plan, for a 28-story building, was finally patented in 1888 but was never used because of lack of appropriate materials and sufficient building knowledge.[12]

There is fairly general agreement that the first skyscraper was the Home Insurance Building in Chicago, built in 1884–86. This 10-story building, designed by W. L. B. Jenny and located at the corner of La Salle and Adams streets, conformed in at least two essentials to the requirements of the modern skyscraper.[13] With a skeleton frame of iron concealed in masonry, it was the first building in the world in which the walls were relieved of supporting the weight of the structure. The economy thus effected was great, and so there was now almost no limit to the height which structures might attain. In addition, the building could be altered and stories added without difficulty or change of style.[14] The 14-story Tacoma Building (1889), though ornamented in Romanesque, conformed to the same standards, as did the Reliance Building (1895), the First National Bank (1896), and the Fisher Building (1897), all in Chicago.

II

In 1871 a fire swept over Chicago, destroying the greater part of the city. Terrible as this disaster was, it nevertheless gave a stimulus to the building art that was little short of miraculous. After 1871 all structures in Chicago were to be made new; this was an opportunity for those who dared to experiment and shake themselves free from architectural restraints. Out of the new Chicago came not only the skyscraper but also Daniel H. Burnham, "the architect who grasped the significance of American industrialism." It was he more than anyone else who cre-

[12] Bossom, *Building to the Skies*, 11.

[13] See Thomas E. Tallmadge, *The Origin of the Skyscraper* (Chicago, 1939). Tallmadge attributes the origin of the high building to the invention of the passenger elevator, which appeared in practical form about 1878.

[14] Bossom, *Building to the Skies*, 15; Fiske Kimball, *American Architecture*, 135–144 (Indianapolis and New York, 1928).

ated the American architect's office as it is today.[15] And it was with Burnham that Joachim G. Giaver, a Norwegian-trained engineer, was closely identified in a building experiment that literally lifted the faces of America's cities.

When Burnham acquired Giaver in 1898, he was more than fortunate in his choice of structural engineer. Giaver had been thoroughly trained in the use of steel and solid foundations in what turned out to be the preparatory school of so many engineers — bridgebuilding. Born in 1856, at Gjøvik, near Tromsø, Giaver came of a prominent Norwegian family, his father being a merchant, a large landowner, and a leading figure in the northern fishing industry. Joachim was tutored at home, as were many of the early engineers, and then went to Trondhjem's Technical College, where he was graduated in 1881 with the degree of civil engineer. He went to America in the following year, and there rose from the position of draftsman to chief engineer of the Schiffler Bridge Company at Pittsburgh. One of his early projects, interestingly and symbolically, was the design of the structural framework in the Statue of Liberty. He also designed several of the bridges over the Allegheny and Monongahela rivers at Pittsburgh.

Rapidly forging ahead as one of the promising structural designers in the country, Giaver went to Chicago in 1891 and became assistant chief engineer for the Columbian Exposition. Quick to sense the importance of windbracing in the framework of buildings, he was put in charge of this feature for the exposition structures. Among other things, he designed the three-hinge arch in the dome of the Liberal Arts Building, then the largest truss of its kind in the world. Burnham met Giaver during the planning of the exposition, and possibly he determined then to invite the energetic Norwegian, when the time was favorable, to become his chief structural engineer. After five years, during which Giaver engaged in general contracting and served as bridge designer for the sanitary district of Chicago, he joined the firm of D. H. Burnham and Company.[16]

[15] Kimball, *American Architecture*, 152.
[16] For accounts of Giaver's career, see American Society of Civil Engineers, *Trans-*

While it is difficult to enumerate the innovations of one man in a work that is essentially co-operative, Giaver nevertheless can be credited with several significant contributions to skyscraper development. He introduced the riveted spandrel girders used between columns to give stiffness to tall buildings.[17] He was also among the first to adopt Mohn's H-shaped columns. He was the very first to use steel sheet piling to reinforce walls, and was a pioneer in the development of Chicago's caisson foundations. In addition, he worked out the system of windbracing generally used by the Burnham company.

During Giaver's long association with Burnham, until the latter's death in 1912, and for several years thereafter as leading engineer for the succeeding firm of Graham, Anderson, Probst, and White, he was responsible for the design of over 400 buildings, including many of the recognized structural landmarks of the country.[18] The period 1898 to 1915 was one in which the modern skyscraper developed from the old spread-footing foundations, cast-iron columns, and wrought-iron framework to the now commonly used caisson or pile foundation and the structural steel skeleton. Giaver's part in this general development can hardly be overemphasized. Such well-known buildings as the Flat Iron, Gimbel, Maiden Lane, and Equitable in New York; the Field Museum, Continental and Commercial National Bank, Railway Exchange, People's Gas, and Conway, in Chicago; the Union Station and post office in Washington, D. C.; the Frick, Oliver, Smithfield, and First National Bank buildings in Pittsburgh; the May Store in Cleveland; and the Wanamaker and Land Title buildings in Philadelphia—these and many others speak for Giaver's engineering skill.[19]

actions, 89:1604 (1926); *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 9 (March, 1929); Strand, *Norwegians of Illinois*, 319; *Scandia*, April 7, 1938; *Skandinaven*, March 1, 1935; *National Cyclopedia of American Biography*, 21:181 (New York, 1931); and the publications of Trondhjem's Technical College. The writer is also indebted to A. C. Bull of Chicago, Giaver's son-in-law, for details of the engineer's life.

[17] *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 9.

[18] For a complete list of buildings raised by Burnham, see Charles Moore, *Daniel H. Burnham, Architect, Planner of Cities*, 2:211–214 (Boston and New York, 1921). In 1915 Giaver opened his own office in Chicago.

[19] Amasa C. Bull, memoir of Giaver in American Society of Civil Engineers, *Transactions*, 89:1604 (1926). It is significant and revealing that in 1915 Giaver took the

III

It is neither desirable nor possible to trace in detail the development of the skyscraper at Giaver's hand; a few of his novel designs, however, attracted the attention of technical journals, and thus records were left for the historian. In the spring of 1910 *Engineering News*[20] devoted some space to a discussion of the building being erected for the People's Gas Light and Coke Company on Michigan Avenue at Adams Street, Chicago. An office structure 21 stories high and about 170 by 195 feet in plan, the new building had a steel frame construction and the usual Chicago foundations consisting of cylindrical concrete piers carried to hardpan at depths of from 80 to 86 feet. The article noted that the upper 18 stories of each street front were carried on cantilevers having a projection of 4 feet, 5 inches. This feature, together with the setting back of the lower sections of the columns from the front of the building, was adopted to permit placing at the building line a row of monolithic granite columns from the sidewalk to the third-floor level; these columns, which served a purely decorative purpose, show how features of the past were grafted to the new style of office building and forced the engineer to produce almost freakish designs. Wind resistance was derived from Giaver's spandrel girders, the wind load being figured at 25 pounds per square foot.

Mention has already been made of the foundation used in Chicago, but since Giaver was one of its leading authorities, a few supplementary words might be added about this skyscraper feature. The tricky nature of the soil in Chicago was demonstrated when the federal post office and customs house, erected in 1877 upon inadequate supports, sank sufficiently to make of the building a virtual fiasco. As a result of this experiment the Chicago foundation was worked out. Wells, or caissons,

leading part in a battle to raise the legal status of the engineering profession. In Illinois previously a structural engineer could engage in construction work only as the employee of an architect, and building plans had to bear the signature of a licensed architect. A state act in 1915 provided for the licensing of structural engineers and made it possible for them to practice on equal terms with the architects.

[20] Vol. 63, p. 294 (March 10, 1910).

were dug to hardpan or rock, and concrete was poured into the wells. The caissons were from 4 to 10 or 12 feet in diameter, depending on the load they were expected to carry. The columns of tall buildings were placed on a nest of grillage beams or solid steel slabs which transmitted and spread the load onto the caissons. The fact that the Chicago foundation was generally borrowed for large buildings elsewhere is proof of its excellence.[21]

The Gimbel Building in New York, which Giaver designed, attracted considerable attention. A department store structure on Sixth Avenue between Thirty-second and Thirty-third streets, the building was completed in 1910. It has 10 stories, a mezzanine above street level, and 3 stories below, giving in all 14 tiers of floor beams weighing, with the columns, about 11,000 tons. The store was built of steel, brick, and terra cotta, and its columns were made of single H-shapes — the type introduced by Richard Mohn.[22]

Giaver, it has been pointed out, was the first to use steel sheet piling to reinforce deep basement walls. This feature, a brilliant innovation at the time of its adoption, has gone out of favor since new and cheaper methods of obtaining the necessary support have been developed. The building in Chicago now called the Marshall Field's Men's Store was one of the first, if not the first structure to employ Giaver's sheet piling in its basements.[23]

The crowning work performed by Giaver, however, was the Equitable Building in New York, which, situated on Broadway and bordered by Pine, Cedar, and Nassau streets, has a location that is considered one of the most valuable in the world — a fact quickly noted by the Norwegian newspapers.[24] At the time of its completion, the Equitable was also the largest office building in the world, having 3 stories below ground, 36 main floors,

[21] A. M. Wolfe (with T. L. Condron), "Chicago Building Foundations," in *Wisconsin Engineer*, 16:149–161 (January, 1912); and J. F. Springer, "Why the Giant Skyscrapers Are Safe," in *Cassier's Engineering Monthly*, 43:35–42 (June, 1913).

[22] *Engineering Record*, 62:120 (July 30, 1910).

[23] *Engineering Record*, 68:677, 715 (December 13 and 27, 1913).

[24] *Minneapolis tidende*, November 27, 1914.

and 2 intermediate stories. It occupied a ground space of a little more than an acre, or an entire city block.[25]

The steel framework of the Equitable was carefully studied and praised by *Engineering News*. The building's large size, according to this journal, was due not so much to its height — such tower buildings as the Singer and the Woolworth were taller — as to its large area of ground plan and the reversion to a normal type of construction which it represented; that is, one carrying the ground plan area up undiminished to the top. Structurally of regular design, the Equitable's columns ran from footing to roof and there were no complicating trusses; as a result, the frame consisted simply of columns, beams, and windbracing. Though only ordinary floor loads were figured on, the weight of the frame was unprecedented; column sections of I-shape were developed to areas of over 390 square inches, about twice the size of such columns used in previous construction. The windbracing, though normal and regular by comparison with that in tower buildings of the Woolworth type, was considered individual in its arrangement; there were eight vertical wind trusses and one horizontal, and because of their number and depth they relieved the columns of considerable concentration of wind load.

Caissons around the outer edge of the building were so arranged as to form a tight cofferdam wall holding back the surrounding earth and water, and steelwork in the basement and sub-basement floors braced this cofferdam wall. The concrete foundation piers were sunk only after considerable difficulty. Bounded by busy city streets that are lined with heavy and fully occupied buildings having foundations on the sand above the tops of the Equitable wall caissons, the soil of the new building lot was "loaded" and great care had to be taken to prevent the displacement of foundations and the transverse movement of the structure.[26]

[25] Edgar Marburg, "Steel Structural Engineering," in *Engineering Record,* 71:9 (January 2, 1915).

[26] "Framework of the Equitable Building," in *Engineering News,* 72:225–229 (July 30, 1914); *Engineering Record,* 70:417 (October 10, 1914).

Besides being the largest office building, the Equitable also gave one of the first practical demonstrations of the skyscraper's fireproof quality. During the night of February 16, 1926, a blaze broke out on the third-floor level in a shaft housing various service pipes. Flames shot up to the thirty-fifth story and came out on that floor because a door of the shaft had been carelessly left open. The fire, however, burned itself out on this floor, doing no serious damage to the building and, in fact, was isolated to one section of the floor.[27]

Giaver's last work was the engineering design for the Jewelers' Building in Chicago, at one time the tallest building west of New York. Discussing this structure shortly before his death, Giaver said that it would be 523 feet high from the upper level of the South Water Street improvement. Located on the southwest corner of Wabash Avenue and South Water Street, the "main building contains twenty-three stories and the tower ten to be rented as office space, and in the upper part of the tower will be space for a club room. The jewelers will occupy from 120,000 to 160,000 square feet of floor space."[28]

What made the Jewelers' Building unusual was a plan to use it for automobile storage as well as for offices. An ingenious mechanical arrangement, almost automatic, was worked out to take cars up and down in the building. It is the writer's understanding that this scheme was never employed, but Giaver, always in league with the future, was convinced "that a multistoried garage can be operated in a building built on fairly valuable property and made to pay as well as an office building on the same property. We confidently believe garages of this type will help to solve the parking problem of congested parts of large cities." Time has demonstrated the shrewdness of his prophecy.

IV

Giaver was the Norwegian pioneer and Chicago the home of the new skyscraper, but it was the Woolworth Building in New

[27] Clark and Kingston, *The Skyscraper,* 109.

[28] "The New Jewelers' Building Skyscraper Garage," in Chicago Norwegian Technical Society, *Year Book, 1924,* 5. Giaver died in 1925.

York, built with the nickels and dimes of the American public, that signaled the triumph of the new structural technique. The steel skeleton and foundations for this, long the world's tallest building, were as great an engineering feat as the concept of its architect, Cass Gilbert, constituted an advance over earlier designs. The engineering work was done by Gunvald Aus and Kort Berle.

The remarkable partnership of Aus and Berle began in the early 1890's when both were employed by the Phoenix Bridge Company, Phoenixville, Pennsylvania; it was renewed when Aus in 1894 appointed Berle his chief assistant at Washington, D. C., where Aus was engineer in charge of all federal buildings; and once again in 1909 when Berle became a partner in the firm Gunvald Aus Company, consulting structural engineers. The history of this partnership is, in itself, an interesting and significant chapter in American engineering.

The senior partner, Gunvald Aus, received his technical education at Bergen and Munich, came to America in 1883, and after a brief period with a locomotive works, was employed by Theodore Cooper, the famous bridgebuilder.[29] At Cooper's, as bridge engineer with the Long Island Railroad, and at the Phoenix Bridge Company Aus acquired the knowledge and skill that qualified him for the position of chief engineer in the office of the supervising architect, treasury department, which planned all federal buildings at home and abroad. In 1902 Aus resigned the Washington position, went to New York, and opened a consulting office.

Berle, trained as a mechanical engineer at Christiania's Technical College, left for the New World in 1887.[30] After working for a short time with Tinius Olsen and the Cramp shipbuilding firm in Philadelphia, Berle went over to the Phoenix Iron Com-

[29] See the able article by Magnus Bjørndal in *Norwegian-American Technical Journal*, vol. 4, no. 1, p. 5 (April, 1931); *Nordmænd jorden rundt* (Christiania), April, 1923; *Morgenbladet*, July 2, 1911; *Minneapolis tidende*, September 26, 1913. When the writer last heard from Aus, in July, 1941, he was living at Vollen, Asker, in Norway.

[30] For his career, see American Society of Civil Engineers, *Transactions*, 100:1602 (1935); Wong, *Norske utvandrere*, 71; *Norwegian-American Technical Journal*, vol. 2, no. 2, p. 12, 16 (July, 1929); and *New York Times*, May 7, 1934.

pany in 1889, later switching to the Phoenix Bridge Company, where Aus was employed. In 1894 he became Aus's first assistant in engineering design for federal buildings; when Aus resigned, Berle became chief engineer in his place. In 1909 Berle, too, left for New York and became a partner of his old associate, and when Aus resigned in 1915 Berle took over control and continued to hold this position until his death in 1934. His firm confined itself strictly to engineering, refusing to enter the general contracting field.

The structural work undertaken by these two men, if properly described, would fill a large volume. For the federal government they made the engineering designs of the customhouse and post office in New York; the post offices and courthouses in New Orleans, Cleveland, Providence, Denver, and New Haven; the Treasury Annex, Washington, D. C.; government wharves at Fort Mason, California; the enormous army supply base at Brooklyn; the federal building at Hilo, Hawaii; the American embassy at Paris; the capitol at San Juan, Puerto Rico; the federal reserve bank in Minneapolis; and the supreme court building in Washington, D. C. In the various states Aus and Berle accounted for the capitol buildings of Arkansas (redesign), Missouri, Washington, and West Virginia; the Eighth Coast Artillery and Squadron A armories, New York City; several county courthouses; and many other structures. Their municipal work includes the public libraries of St. Louis, Detroit, and St. Paul; auditoriums in Portland, Oregon, Youngstown, Ohio, and Macon, Georgia; municipal buildings in Springfield, Massachusetts, Chester, Pennsylvania, and Waterbury and New Haven, Connecticut; not to mention hospitals and memorial foundations. Buildings abroad include a giant steel arch bridge in Costa Rica; hospital structures at Chang Sha, China; an office building in Jemshedpur, India; mills at Delagoa Bay, South Africa; the powerhouse, Dolores Mines Company in Mexico; the Masonic Temple, Manila, P. I.; the Carnegie Library, San Juan, P. R.; and the American cemetery, Surrey, England.

But the tall structure in America was the Aus-Berle specialty, if indeed they can be said to have had a specialty. They planned over 50 apartment houses in New York City, varying in height from 10 to 20 stories; the Roosevelt and Monteleone hotels in New Orleans; the Ritz Tower in New York City; Hotel St. George, Brooklyn; the Aetna Insurance Building, Hartford, Connecticut; the Penn Mutual Building, Philadelphia; the Prudential Building, Newark, New Jersey; the Union Central Insurance Building, Cincinnati; and the New York Life Building, New York.[31]

The Gunvald Aus Company did the engineering work for a great number of churches, banks, warehouses, powerhouses and general industrial buildings. At Yale University they erected the Harkness Memorial Quadrangle, the Elm dormitories, Trumbull College, the Berkeley dormitories, Timothy Dwight College, and the library building; at Northwestern University, the buildings erected between 1927 and 1932. They put up the student housing and administration buildings at Atlanta University; the Colgate-Rochester Divinity School; the Niriam Osborn Home, Rye, New York; the Columbia University library; the Columbia Medical School housing and the Eye Institute, Medical Center, New York City; the Academy of Arts and Letters, New York City; Huntington Seminary, Long Island; a classroom building at Fordham University; the Union Building at the University of Wisconsin; St. Michael Novitiate, Englewood, New Jersey; the Seaside Hospital and Employees Home at Waterford, Connecticut; and many other similar structures.[32]

The purpose of enumerating these buildings, erected both before and after the Woolworth Building, is only to demonstrate that, regardless of what architects may have thought, for Aus

[31] It is interesting to note that this colossal building was erected on the site of the old Madison Square Garden, the steelwork of which was designed by Berle when he was with the Phoenix Iron Company; *Norwegian-American Technical Journal*, vol. 2, no. 2, p. 16.

[32] This partial list of buildings was supplied by S. F. Holtzman, a present member of the Gunvald Aus Company. A similar list is given in *Norwegian-American Technical Journal*, vol. 2, no. 2, p. 12, 16.

and Berle the giant tower was merely another engineering project — with new and difficult problems, it is true, but still something to be taken in stride. Experienced builders with a reputation for work of the first order, they were entrusted with seeing to it that the Woolworth Building, as conceived by Cass Gilbert, would endure.

V

It is a source of some irritation to engineers as a group that the architect is at times publicized in connection with some new or revolutionary undertaking, while in reality it is the engineer who is more deserving of the plaudits. A statement by an engineer who is in harmony with this protest has been recorded in connection with the Woolworth Building. While acknowledging Gilbert's architectural skill and vision, the engineer nevertheless insists that what the architect did for the Woolworth was merely to "formulate its Gothic, church-like lines and to design its exterior and interior decorations," to lay out the "plans of its sixty floors," and to decide "where there should be a window, where the corridor, and where the elevators should be located." The next and most vital step was to call in the engineers to design the "enormous steel structure that forms the backbone of this young giant. They also had to dig down to bedrock and design the massive foundations upon which these thousands and thousands of tons of steel and brick should rest. It was not the architect who guaranteed that the building would stand forever." [33]

Nevertheless, even before the night in April, 1913, when President Wilson pressed a button in the White House and caused 80,000 lights to flash throughout the building, there was general agreement that the Woolworth was "in every inch a proud and soaring thing." Cass Gilbert's reasoning must have followed a line similar to this: America has made a religion of business, despite a certain lip service to the traditional churches. Mr. Woolworth, of five-and-ten-cent store fame, is a kind of

[33] Magnus Bjørndal, "Kort Berle, Designer of Tall Buildings," in *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 12.

priest of the new religion. He symbolizes a good deal of American idealism, the sound variety as well as the perverted. Why not, as one writer suggests, "treat the mart more or less as a temple, lavishing upon it all our best?"[34] Considerable progress has since been made in shaking off the restraints of the past—chiefly through the efforts of the Finn, Eliel Saarinen—but the Woolworth remains "one of the great architectural creations of all time"—the "great example of the triumph of the perpendicular over the horizontal motive"—and it fortunately "closed the period of Eclecticism."[35]

A Gothic masterpiece when studied from a strictly architectural point of view, the Woolworth Building is even more interesting when analyzed from a technical viewpoint.[36] Exceeded in height only by the Eiffel Tower, the structure as planned in 1910 called for 69 concrete piers carried down to solid rock by the pneumatic caisson process. No wood or other inflammable material was to be used anywhere in the building; windows, doors, and the like were to be made of pressed steel and the floors of mosaic, while the tower was to be "sheathed with tiles and covered with copper." When completed in 1913, the building contained 24,000 tons of steelwork, rose to a height of 760½ feet above the curb, had a space content of 13,200,000 cubic feet above the subbasement, and cost $7,500,000. The main portion of the building was only 30 stories in height, the upper half consisting of a 25-story tower about 85 feet square. The structure was notable for its heavy column sections, some of which exceeded in weight any previously used. The largest column had a cross section of 700 square inches and carried a maximum load of about 4,740 tons, of which 1,300 tons was to be wind load. A remarkable building indeed, and one which called for universal admiration.

Of invaluable aid to an understanding of the structure is an

[34] Bragdon, in *American Mercury*, 22:291.
[35] Tallmadge, *Architecture in America*, 256.
[36] See *Engineering Record*, 63:591–593 (May 27, 1911), 64:256 (August 26, 1911), 65:714 (June 29, 1912), 66:97–100 (July 27, 1912), and 68:22–24 (July 5, 1913); *Engineering News*, 72:232 (July 30, 1914); and *American Architect*, 103:157–170 (March 26, 1913).

article by Gunvald Aus titled the "Engineering Design of the Woolworth Building," in which the author surveys the problems met in planning and construction and offers an excellent answer to the question, how the modern skyscraper appears to the engineer who helped build it.[37] "The use of steel for the support of the walls of buildings," he writes, "permits constructions, that were never dreamed of by the architects of old, and unfortunately permits all kinds of freak designs. From an engineering point of view, no structure is beautiful where the lines of strength are not apparent, or in other words, where one cannot follow the distribution of the loads from the top of the structure to its foundations."

Fortunately architects are gradually recognizing that steel and stone should act together in such a way that one does not have to guess the support of an apparently unstable structure, although there are still a few who have the idea that the steel frame is merely a necessary evil, and that the structural elements should be as far as possible concealed, so that the building gives the impression of a masonry construction, whereas in reality the high modern buildings are essentially steel cages with the masonry forming only a veneer, or an enclosure, which serves the object of making the buildings habitable and beautiful, but where the walls have lost the function of supporting the floors and the roof, and are themselves supported at every floor by horizontal girders between the columns.
This should be acknowledged in the architecture, which obviously should be so designed as to clearly indicate the location of the supporting elements.

With respect to the columns, the location of the Woolworth Building "is such that the renting agent insisted on a certain maximum and minimum size of office, and these requirements were practically responsible for the spacing of most of the columns in the wings of the building. In the tower proper, the column spacing was determined largely by the architectural requirements, that is to say, the front elevation and the space required by the elevators."

Having determined the location of the columns, the next point that generally in a high building causes considerable debate is the wind bracing. The architect is very apt to think that the engineer

[37] In *American Architect,* 103:157–170.

requires too much space for the wind bracing, both in the interior of the building and in the walls. After considerable discussion it was determined that the most suitable bracing for the tower . . . was a system of portal braces, as these could be concealed in the piers of the exterior walls and in the partitions enclosing the elevators.

It was, however, found feasible to utilize full triangular bracing between certain of the interior columns in the tower, and as this form of bracing requires less steel than the portal braces, it was adopted in places where it could be used. For the two wings of the building a system of double plate girders, riveted with gussets to each side of the column, was adopted, and the gussets which projected below the bottom of these girders were omitted as soon as the bending stresses could be taken care of within the depths of the girders. This form of bracing is generally best adapted for interior transverse bracing, as it is not much in evidence in the finished building, whereas knee braces or gussets are very objectionable when exposed in the larger offices.

To the layman the foundations of skyscrapers remain little short of miraculous. In the case of the Woolworth Building the problem of sinking foundations was unusually complicated. "The subsoil . . . consists of a very fine sand to the depth of approximately 110 feet below grade. At this level," Aus records, "hard rock is encountered. It became therefore in this case easy to decide that some method of foundation had to be adopted which would penetrate the sand and make the foundations rest directly on the hard rock, and under the given conditions pneumatic caissons were almost a necessity."

Originally Woolworth had not secured the entire block fronting on Broadway between Park Place and Barclay Street. In the original design, therefore, the corner on Barclay Street was omitted and the tower was not centered in the block (as it was later in actual construction) but was located nearer to Park Place. The contractor had a number of caissons in place before the owner purchased the Barclay Street corner and ordered the re-design of the entire building.

How to utilize the tower foundations, which were already in place now became a very different problem, as these foundations did not come under the columns as located in the new design. After careful study it was decided that the new columns could always be on line with the columns in the original design, and that addi-

tional caissons could be put on these lines, so that the columns could be supported on plate girders between the two adjacent caissons . . . . Wherever the caissons had not already been put in, they were shifted to the new position, so that they came directly under the columns.

It may be noted that the height of the tower was very materially increased in the new design, so that the old and new caissons combined in most cases were only large enough to support the load coming from the columns. It should also be noted that the additional caissons were, as far as possible, so spaced with reference to the columns' centers and the old caissons as to distribute all that part of the load that could be carried by the old caisson, to it.

In other words, that the center of the column would be as far as possible in the center of gravity of the cross sections of the combined caissons.

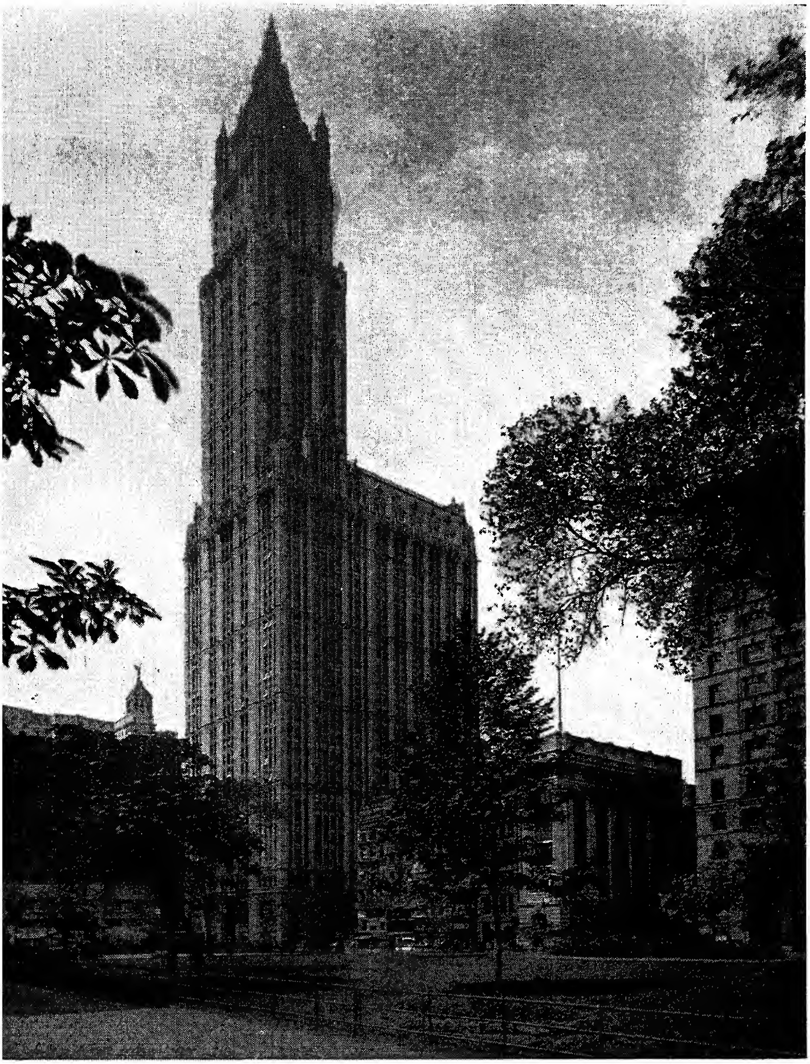
The very deep box girders which became necessary to bridge the opening between the two caissons were surrounded with a rich concrete twelve inches thick on the bottom of the girder and six inches thick over the extreme projections, and the space between the girders is carefully filled with the same concrete, so as to protect the steel thoroughly against corrosion. The concrete which surrounds and fills these girders, and in fact all other beams and girders in the foundation, adds enormously to the carrying capacity of such girders and beams; in many cases it fully doubles the bending strength of such girders and beams.

Aus was irked by a borough ruling to the effect that no part of a foundation could extend beyond the building line, and he makes no secret of his pique, for the ruling handicapped him greatly. It was necessary "to cut a segment off from the one caisson on Broadway, whose diameter was so great as to make this caisson project beyond those already in place, and along Barclay Street it became necessary to use the narrowest caisson that can be constructed for such great depth, which is about six feet, and move the wall columns three feet back from the building line, or to the center of these caissons." Aus argues in favor of a reasonable projection beyond a private lot into the city's property, provided the owner is willing to pay for the space; engineers would thus be spared many difficult foundation problems. While on the general subject of city building regulations, Aus also asks for a revision of New York's building code, which he insists was the cause of many "irrational designs." Because

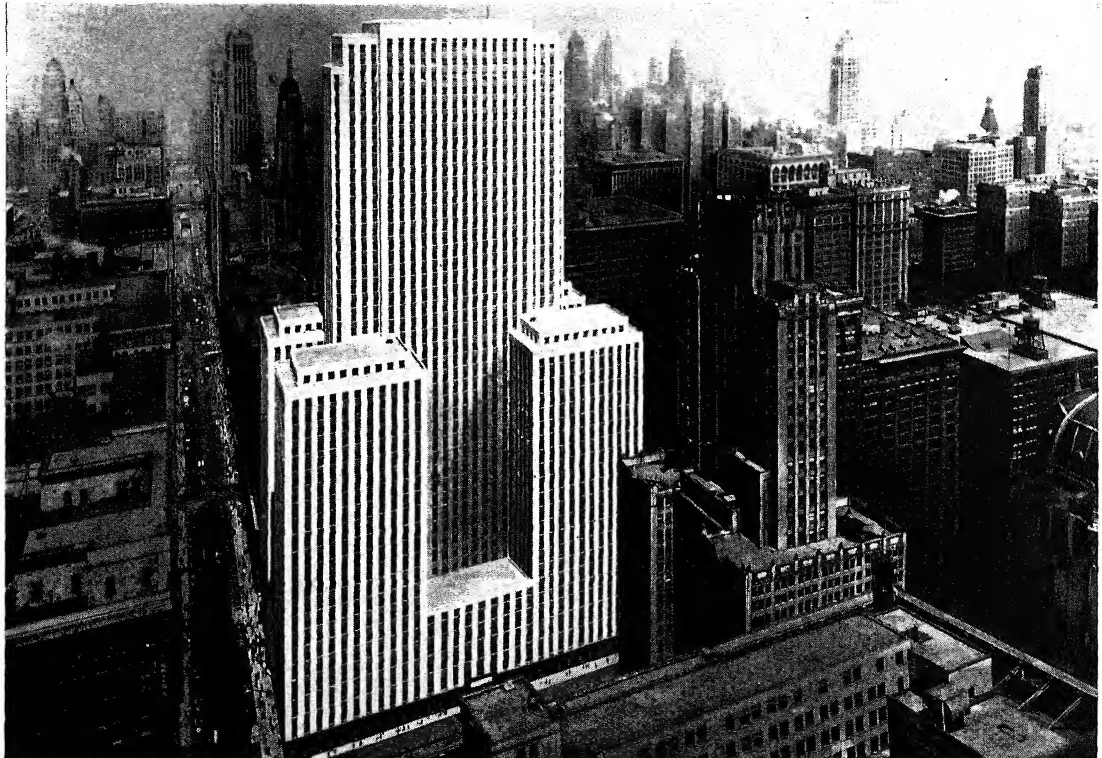
the codes of most cities demanded that all foundations be designed for either the full live load or a very large part of it, the wall columns "receive practically all the load, for which they are figured, and transmit this load to the foundations. The interior columns carry only the weight of the floors and the movable live load, which will probably never be more than a fraction of the load, for which they are figured, and this movable load does not come on the columns until long after they are erected. The result will be that the wall columns, if supported on a yielding foundation, will settle considerably, because they receive practically the full load, for which they are figured, whereas the interior columns together with their foundations will not compress the subsoil, and therefore they will not settle."

Discussing the structure's columns, Aus says that when "a building is erected as high as the Woolworth Building, the loads on the columns including the wind load become so great as to approach the limit of practical construction. The columns are of necessity built up of plates and angles, and as the lateral dimensions must be limited, so as to occupy the least practical floor space, the thickness becomes very great. It was found impossible to design columns in this building with a dimension of about three feet by four feet without using rivets, which had as much as five and one-quarter inches grip. The rivets were made one inch in diameter, in order to allow for this great length of rivets, but even then it is a question whether five inches is not about the permissible thickness of metal, and hence it would seem that it is not practical to design a building much over 800 feet high, unless the columns are spaced closer together."

It may, of course, be possible to use a steel of greater resistance than the commercial steel, as for instance nickel steel, but so little data exists as to the strength of such enormous built up sections, that I do not believe it would be safe to use stresses much higher than those employed in the Woolworth Building, that is, about 14,000 pounds in compression on the lower tiers of columns. The actual stresses are, of course, very much smaller than those assumed, because the building law calls for a live load of seventy-five pounds per square foot, and a reduction of only five per cent per



Woolworth Building



Field Building

floor down to a minimum live load of fifty per cent, or thirty-seven and one-half pounds for all the lower floors.

Now, it is a well known fact that the actual live load in an office will not exceed ten pounds per square foot, and it would therefore seem rational to allow a very much greater reduction of the live load, for which columns are designed. . . . If such a reduction was allowed, and if walls could be made only sixteen inches thick for three or four stories and twelve inches thick for the entire height of the building above, it would, of course, be possible to erect a building possibly not less than 1,200 feet high, and such buildings will probably be erected under special conditions in New York, if the Building Law can be so amended as to permit the construction of thinner walls and the consequent reduced live load that would be imposed.

Coming back to windbracing, the writer informs us that according to New York's building code at the time the Woolworth tower was erected, the building "must be designed to resist a lateral wind pressure of thirty pounds per square foot over the entire area of the building. This is a very excessive requirement, as all observations have shown that while the pressure of the wind over a very limited area may be fifty pounds per square foot or even more, it is only a very small part of a building, that is exposed to such great pressure, and that in other parts of the building the pressure may be zero, or in actual suction, that is negative pressure, so that the total resulting pressure will probably never be as much as ten pounds per square foot over the entire area."

However, the Woolworth Building was designed for the full load of thirty pounds per square foot, and the system employed was, as already stated, portal bracing in the tower. . . . This is a rather expensive form of wind bracing, as the material in the portals is not strained in direct tension and compression, as is the case with diagonal bracing, but on the other hand, the portals can generally be arranged so as not to interfere with window openings, and the piers in the tower can be made very much lighter than would be possible with a system of diagonal braces.

For the upper part of the tower, that is to say about the twenty-eighth floor, it became possible to use a system of corner braces without interfering with the window openings, and it would undoubtedly have been possible to utilize this system in a number of places further down in the tower, but I believe that the great rigidity, which is found to exist in the tower, is due mostly to the sys-

tem of portal braces, and that the money spent on this system of bracing is a very good investment, as not the slightest tremor can be observed on the top of the tower, even in a very heavy wind.

The two lower floors of the building were constructed of reinforced stone concrete, and the columns were cased with concrete. This construction, Aus tells us, was adopted in order to provide a "continuous sheet of great strength which would transmit the wind loads into the retaining walls, which in turn are held by the surrounding subsoil." For the upper floors terra cotta fireproofing was used for all the columns, and the floor arches were made "of hollow blocks of end construction." Aus believes it would have been much better, structurally, to use a system of reinforced concrete floor arches throughout the building, "but the long time required in placing the reinforced concrete, and also the difficulty of working in freezing weather made it practically impossible to use such concrete for floor arches and fireproofing of columns, although the cost including suspended ceilings, which were required throughout all the offices, was somewhat less than the flat terra cotta arches. The great advantage of easy setting, and the absence of dirt and water incident to the placing of concrete arches, and the splendid plastering ground formed by the flat soffit of the terra cotta arches, decided in favor of this latter construction."

It is evident that the question of paint was given a great deal of study by the engineers of the Woolworth Building. "There is probably no more important consideration in a steel skeleton building, than the proper protection of the steel against corrosion, which is not only caused by air and moisture, but also, and under special conditions to a much greater degree, by vagrant electric currents passing through the steel members and thus inducing what is popularly termed electrolysis." Aus doubted that it was possible entirely to protect steel against electricity by painting, but he felt that certain paints, containing various asphalts or tar products, insulate the steel to a considerable extent. "As a protection against ordinary rusting the ordinary red lead paint . . . is probably unexcelled, and it

was therefore finally decided to paint the steel work in the Woolworth Building with two coats of such red lead paint, and a final coat of waterproof paint, which would protect the red lead against the attacks of the free lime in the cement, and to some extent insulate against vagrant electric currents."

VI

Magnus Gundersen may be said to have continued the work begun by Giaver in the field of the tall office building.[38] Going to Chicago in 1910, only a few months after graduating from Trondhjem's Technical College, Gundersen had his first practical experience in design of reinforced concrete with the Julian S. Nolan Company, and in structural steel with Morey, Newgard and Company. In 1913 he took a position as draftsman and designer with the D. H. Burnham Company, which the next year became Graham, Anderson, Probst, and White. Gundersen worked under Giaver's inspiring leadership until 1915 and under Giaver's successor, William Braeger, until 1927, when Gundersen was made chief structural engineer for the firm. In 1938 he went into independent consulting work.

In his capacity as engineer with the famous Chicago architectural firm, Gundersen was responsible for the structural design of a number of outstanding buildings. Among them was the one at 20 Wacker Drive, a 45-story structure that was planned as a combination office building, opera house, and theater. Completed in the late 1920's, it contains in its south and middle portions the auditorium for the Chicago civic opera, with a seating capacity of 3,300 and a height equivalent to a 6-story building. The north portion of the structure is occupied by the civic theater, which has a considerably smaller seating capacity than the opera house. Since the civic opera has always operated at a financial loss, it was decided in planning the building on Wacker Drive that offices should be included as a means of supplying extra income for the musical organization, thereby

[38] See *Norwegian-American Technical Journal,* vol. 2, no. 3, p. 7, 16 (November, 1929); *Skandinaven,* March 1, 1935; Alstad, *Trondhjemsteknikernes matrikel,* 281; *Nordmanns-forbundet,* 28:353 (October, 1935).

making the opera a self-supporting public institution. From the eighth story and up through its tower, 20 Wacker Drive is therefore an office building with the column spacing required of such a structure.

The resulting problems of design and construction were many. From the street level to the eighth floor the requirements of the opera and theater were such that columns, which would normally be located in the spaces occupied by the auditoriums and stages, had to be brought over to new locations so as not to create annoying obstructions. This was accomplished through the use of large trusses and heavy girders. Part of the tower section of the building, which rises 37 stories to form a skyscraper, rests on trusses that span the main auditorium. The pin connections in the trusses were made of special steel to a diameter as great as 22 inches. Windbracing was complicated by the large, open auditoriums and stages in the lower portion of the structure, where wind stresses are the greatest. A further and obvious difficulty in construction was met in the Chicago River, which runs along the west side of the building. And, finally, it was necessary to sink concrete caissons to rock about 105 feet below the sidewalk.[39]

Shortly after the planning of the Chicago opera building, architects and engineers in Graham, Anderson, Probst, and White were busily at work on designs for the famous Chicago Merchandise Mart. The owners, Marshall Field and Company, sought in this enormous structure not only facilities for an extensive wholesale trade, but also a single roof for representatives of concerns doing business with Marshall Field. Completed during the early years of the depression, the Merchandise Mart was proclaimed the largest building of its kind in America, containing a floor area of about 4,000,000 square feet, or more than 90 acres, and having a frontage on Kinzie Street of 724 feet, 580 feet on the Chicago River, and 400 feet on Wells Street. The

[39] *Engineering News-Record,* 103:758 (November 14, 1929); and *Norwegian-American Technical Journal,* vol. 3, no. 1, p. 1, 12–14 (February, 1930). The writer is indebted to Gundersen for descriptions of this and other buildings in whose construction he participated.

main building is 18 stories high, but a tower extends 7 additional floors. It required in all 53,000 tons of structural steel, and 6,000 tons of reinforcing steel for the concrete floors.

It should perhaps be pointed out that the "Mart" is an air-right building; that is, it occupies only the space from the sidewalk and up, except for the room below required by columns and foundations. The balance of the space below the first floor is occupied and owned by the Chicago and North Western Railway and is used for tracks and a freight station.[40]

The next large building constructed in Chicago was the new post office. The old structure, built near the close of the last century, was inadequate to handle the volume of mail distributed by the postal officials in 1930, despite the fact that a separate parcel post building had been erected in the 1920's. As a result, the federal government ordered a new post office, to be located between Van Buren, Harrison, and Canal streets and the Chicago River, with a passageway in the middle of the building to permit the proposed Congress Street to pass through. Another air-right structure, built over the tracks leading to the Union Station, the post office is a combination of two distinct units. The north part, which houses the administrative offices of the postal department and several other branches of the federal government, is a typical office building, while the south unit, where mail is handled, is of a heavy-duty type of construction.

The Chicago post office, one of the largest and most modern mail-handling buildings in the country, has mile after mile of conveyors, chutes, and elevators for receiving, sorting, and distributing mail—for local distribution as well as for reshipment to other cities. But from an engineering viewpoint the greatest significance of the building lies in the type of structural steel used in its framework. Of the total 44,000 tons employed, more than half were of silicon steel. Though silicon steel had been used before in isolated cases where members of carbon steel

[40] *Engineering News-Record,* 103:420 (September 12, 1929); and *Norwegian-American Technical Journal,* vol. 3, no. 2, p. 4, 6 (August, 1930).

tended to become too heavy, the Chicago post office was the first building to employ this material extensively and advantageously, and its erection therefore marked a step in the advance of steel construction.

Among the remaining structures for which Gundersen was responsible as structural engineer was the Field Building, which rises 44 stories to a height of 535 feet in the heart of Chicago's loop. Completed in 1934, the Field skyscraper occupies the site of the old Home Insurance Company building, which has been mentioned earlier as the first skyscraper, and which had to be taken down to make room for the new structure. The Field Building was designed primarily for office purposes but it provides banking space in the lower stories, and shops on the ground and basement levels. A strikingly modern building of strictly vertical design, it also has the latest types of cooling, dehumidifying, and ventilating equipment, as well as air conditioning on the lower floors. It contains about 22,500 tons of steel and its columns rest on concrete caissons going down to rock at depths of from 80 to 100 feet.[41]

Engineers are occasionally called upon to alter existing structures while permitting business to continue with a minimum of interference. When the First National Bank in St. Paul, occupying a 16-story building, decided to add to this structure and change the design of its banking room, Gundersen was called in to perform the operation. Two rows of columns had to be removed in order to satisfy the new bank plans. While the addition to the building was being constructed, heavy transfer girders were erected in the fourth story on both sides of the columns that were to be removed from the banking room immediately below. In addition, new reinforced support was constructed for the transfer girders. Heavy brackets were connected to the columns in the fourth story, and with the aid of hydraulic jacks having a capacity of more than 1,000,000 pounds, the loads on the columns were transferred from the foun-

[41] See Magnus Gundersen, "Design of the Field Building, Chicago," in *Civil Engineering*, 5: 631–635 (October, 1935).

dations to the transfer girders and their support. After the load had been transferred and the calculated deflection in the girders had been obtained, the columns were connected permanently to the girders and burned off just below the bottom flanges of the transfer girders—thus providing the desired open space in the banking room. This feat was accomplished with the building fully occupied above the fourth floor and without causing the slightest damage to the bank.

Gundersen also designed the engineering features of the Alamo Bank Building in San Antonio, the Bryant Building in Kansas City, the addition to the Washington (D.C.) post office, the O'Neil department store and the Mayflower Hotel in Akron, the Higby Store in Cleveland, the Koppers Building in Pittsburgh, the main Pennsylvania Station and office building in Philadelphia, the Northwestern Bank Building in Minneapolis, and the Belknap and Heyborne buildings in Louisville—to mention only the more important structures outside Chicago.

The close relationship between tall buildings and subways has already been noted. When Chicago recently decided to build a subway system, Gundersen was called in as a consulting engineer to solve the problem of underpinning and support in those places where the subways were to be constructed below existing buildings. Under his direction, supports consisting of new caissons and transfer girders were installed for the first time in Chicago. Performances were actually given in theaters while this work was being done immediately below.

Large, jovial, and competent, Gundersen, before his death in January, 1946, gave proof of his ability to continue the tradition of Giaver, Aus, and Berle in the field that is truly America's gift to the art of building. These Norwegian-trained engineers, together with many of their own countrymen and with men of other national origins, have had a leading part in erecting the "campanili of the New Feudalism" which now form the skyline of America's many cities.

MEN IN METALLURGY

OURS has been variously called an age of steam, electricity, petroleum, glass, or plastics, and certainly it owes a peculiar debt to all these forces and materials. But underlying all technology are certain vital minerals, without which the conduct of modern life would indeed be difficult, either in war or in peace. Production, whether it concern itself with bridges, skyscrapers, tunnels, ships, industry, railroads, or the many other phases touched upon in this volume, calls for building materials in greater quantities and ever-improved quality. The smelting and processing of steel, copper, nickel, and other metals and their alloys constitute in themselves a significant branch of engineering. It is therefore natural that a number of Norwegians should have been attracted by the possibilities in New World metallurgy, have become involved in the world-wide activities that are associated with it, and have contributed significantly to its development.

I

The individual dominating almost any discussion of metallurgy is E. A. Cappelen Smith, since 1925 a partner in the well-known firm of Guggenheim Brothers and for a long time before that director of research for the same company. The history of this engineering giant includes a revolution in copper converting, the origin of the Chuquicamata method of extracting copper in Chile, the discovery of the Guggenheim process used to take saltpeter from Chilean *caliche*, and the development of a biochemical method for treating sewage. In the background of Smith's story we find the struggle to reduce copper production costs, a world competition in nitrates, international

diplomacy, and the operations of a great cartel. Here indeed is a tale of modern pioneering the like of which is rarely told; but only its outline, with emphasis on the technical aspects, can be recorded in this book.

Cappelen Smith was born at Trondhjem in 1873, the son of a wholesale merchant of iron and steel products.[1] He attended Latin school and the technical college in his native city. He graduated from the latter in 1893 with the degree of chemical engineer; it was his intention to continue his chemical studies at Charlottenburg in Germany.

But 1893 was also the year of the Columbian Exposition in Chicago, an event which attracted engineers from every country in Europe, among them Cappelen Smith. Thus began a "visit" that was to continue through a long and productive life. Caught up in the whirl of a rapidly expanding New World economy, Smith took a job in a Chicago laboratory, later transferring to Armour and Company as assistant chemist in their Chicago plant. His task was to find methods of utilizing the by-products of the meat-packing industry, a field in which great progress was made later. Today, looking back upon his early years, Smith is aware of the many opportunities that lay within his reach had he stayed with Armour. After two years at the stockyards, in 1896 he accepted a position as chemist with the Chicago Copper Refining Company. While working in their laboratory at Blue Island, about forty miles south of Chicago, he began his first studies in metallurgy. Smith learned smelting from the ground up, supplementing his theoretical training with practical experience of the best kind. Thereafter the story of his life moves unfalteringly, if somewhat circuitously, toward his first major contribution to the metallurgy of copper.

Smith was not, however, satisfied to remain in the Chicago area. The restlessness common to most young immigrants caused him to give up his job and set out for Anaconda, Mon-

[1] This section is based on a number of sources, chiefly two articles in *Nordisk tidende,* December 6, 1923, and November 24, 1938; an interview with Cappelen Smith, May 20, 1941; and scattered bits of information in popular and technical journals.

tana, the copper El Dorado of the West. His sights were raised high enough; at the age of twenty-three he sought nothing less than the superintendency of the electrolytic refinery owned by the Anaconda Copper Mining Company. Facing Marcus Daly, the copper king, Smith was told that he was too young, but was given the position of chief chemist. One month later he was superintendent, and he held this position for four years.

Restlessness again overcame Smith, leading him this time to the west coast. In Republic, a little town in northern Washington, he organized a company whose purpose was to extract gold from local ores. Machinery was set up and everything was in order for the start of operations when the man who had financed the project suddenly died. Unfortunately for the experiment, the heirs of the financier had no interest in the company but were intensely interested in his money. Smith's career in the American West, as a result, came to an abrupt end.

In September, 1900, Smith visited Norway, remaining in Trondhjem until January of the next year. Upon his return to the United States, he became assistant to the engineer in charge of metallurgical operations at the Baltimore Copper Smelting and Rolling Company. During the years he worked in Baltimore, new metallurgical methods were coming into use. Men were experimenting with converters and borrowing the lessons learned in steel production. Smith missed nothing; he was determined to make the most of New World possibilities in the field of copper, and it was in this field that he achieved his first great success.

In 1907 the Guggenheim Brothers bought control of Smith's firm, and in 1912 he became their general consulting metallurgical engineer. Thereafter he held many additional offices. He was for a time president and director of the Anglo-Chilean Consolidated Nitrate Company, the Lautaro Nitrate Company, Limited, and Cosach (Compañía Salitrera Anglo-Chilena). At present he is a member of the firm of Guggenheim Brothers; president and director of Minerec Corporation; and director of the Chilean Nitrate Sales Corporation, the Anglo-Chilean Ni-

trate Corporation, the Lautaro Nitrate Company, Limited, and the Pacific Tin Consolidated Corporation.

II

It was during the early years of the twentieth century, from 1901 to 1912, that Cappelen Smith made his first contributions to the metallurgy of copper. In those years he helped put into general use an improved method of furnace refining that introduced air under the surface of molten copper, thus borrowing a principle long employed in steel production and more recently in the copper industry; it made possible the present-day use of giant furnaces for copper smelting. Mention should also be made of his new method of treating the precious-metals slimes obtained in electrolytic refining; of the recovery on a commercial basis of selenium, tellurium, platinum, and palladium from the same slimes; and of the production of nickel salts as a by-product of copper refining.[2] His major contribution during this period, however, was his new method of basic copper converting, a method that revolutionized smelting practices and was immediately adopted by every large copper producer in the world. With his superior at Baltimore, Smith built a furnace embodying the principle of basic lining and employing his improved Bessemer techniques. They then began a successful venture in manufacturing the new product.

It is well at this point to explain that there are in use today several methods of extracting copper from its ore. The first method, commonly used in the Lake Superior region where the mines are underground, is to crush the ore and then send it to what is known as a concentration mill. There the copper is separated from the waste and then sent to a smelter to be treated in reverberatory furnaces. Air blown through the molten copper oxidizes the impurities. The second, or leaching, process is used most commonly in the pit or surface type of mining. After the copper ore is crushed, it is placed in huge vats where

[2] From a summary of Cappelen Smith's work prepared in the Guggenheim offices, New York City.

leaching solutions, acidified with sulphuric acid, percolate through the ore. The acid, when it unites with copper, forms a copper sulphate solution which passes to an electrolytic tank house, the waste being left behind. In the tank house an electric current is shot through the copper solution, resulting in the deposit of metallic copper on cathodes. The cathodes, after they are sufficiently built up with copper, are sent to reverberatory furnaces, where they are melted and cast into commercial forms.

The third method is used in ores rich in sulphur content. The copper concentrate goes from a concentrating mill to a roasting furnace where the sulphur is driven off and other impurities oxidized. Proper fluxes being added, the copper is melted in reverberatory furnaces and the floating slag is removed through a taphole on one side of the furnace. The matte — copper containing iron, sulphur, and precious metals — collects in the bottom of the furnace and is removed in ladles. The matte while in a molten condition is dumped into converters, where it is Bessemerized; that is, air is forced through the molten matte, the mass being heated by the oxidation of the sulphur in the metal. Two products are thus produced — copper, and a slag composed of silica, aluminum, and other materials, including a small amount of copper, which is later reclaimed. The sulphur is eliminated through the chimney as gas. Copper produced by this method is known as blister copper and has a purity of about 98 per cent; the remaining 2 per cent consists of such impurities as gold, silver, and other metals.[3]

The origins of modern copper converting go back to the work of Sir Henry Bessemer, who in 1856 introduced the method of blowing air through molten cast iron in the production of steel. The Bessemer process, so successful in turning out a quality steel, was first applied to copper on a commercial scale by Manhès in 1880. In 1883–84 the Manhès converter, with a ca-

[3] Copper and Brass Research Association, "The Copper Industry," in John George Glover and William Bouck Cornell, *The Development of American Industries, Their Economic Significance,* 384–386 (New York, 1935).

pacity of from 7 to 10 tons, was introduced into the United States. This converter was acid lined and the lining was quickly consumed in the converting process.[4] Attempts were made at an early date to introduce a basic or neutral material such as chrome or magnesite brick as a lining for the converter, the purpose being to eliminate chemical action between the lining and the molten mass in the converter. To Cappelen Smith goes the honor of successfully introducing basic lining on a commercial scale.

When Smith was employed by the Anaconda Copper Mining Company in the late nineties and was temporarily in charge of its tilting furnaces, he began to experiment with the idea that later developed into the basic-lined converter. He was not alone in this work; Ralph Baggaley conducted similar experiments at Butte, Montana, about 1903. In Norway still other work of a similar nature was carried out. But it was Smith's efforts at Baltimore that finally put a successful product on the American market. Free at last to experiment, and encouraged by William H. Peirce, his superintendent and manager, he produced in 1908 a magnesite-lined converter for leady copper mattes. "To Smith and Peirce belongs the credit of taking a long-discarded idea and developing it into a successful product."[5] To posterity the very name Peirce-Smith converter will suggest a dual contribution, and justly. By making it possible for Cappelen Smith to work at the problem of conversion, Peirce immortalized his name along with that of his brilliant associate.

The Peirce-Smith converter could produce 3,000 tons of copper, instead of the former 10, without relining. This figure was later increased to 40,000 tons. Needless to add, the effect on the copper industry was nothing short of revolutionary. Before the new converter was put into use, the cost of converting

[4] Milo W. Krejci, "Development of Copper Converting," in *Engineering and Mining Journal,* 104: 669–674 (October 20, 1917); Donald M. Levy, *Modern Copper Smelting,* 192–195 (London, 1912).

[5] E. P. Mathewson, "Development of the Basic-lined Converter for Copper Mattes," in American Institute of Mining Engineers, *Transactions,* 46: 473 (1914). When Smith's converter underwent its first real test, he stood for 72 hours on the converter's platform, exhausted but confident of success; *Nordisk tidende,* November 24, 1938.

copper was from 15 to 20 dollars a ton. This figure was quickly reduced to 4 or 5 dollars by the new process—one which authorities had confidently asserted would not work.[6] The most important feature of basic lining is, of course, its permanence. By eliminating frequent relinings the new converter permitted many plant economies, both in capital investment and operating costs. It was no longer necessary to haul converters frequently to the repair shop—a fact which in turn made possible the use of larger converters and increased "the ultimate possibility of continuous operation." The converters that were immediately put into operation were about 26 feet by 12 feet in size, with a capacity of 35 to 45 tons of matte and a daily output of 33 tons of copper from 40 per cent matte.[7] The daily output was soon increased to 125 tons or more.

The steel vessel of the early Peirce-Smith converter was lined with magnesia brick at least 9 inches in thickness, except at the air openings or tuyeres, where it was 18 inches thick; its bottom was lined with ordinary firebrick. The magnesite bricks were laid in dry magnesite powder, except near the tuyeres, where linseed oil was mixed with the magnesia. Inserted at intervals along the side of the fresh linings were so-called expansion cushions of wood which were "seasoned" with molten copper. A siliceous flux was dumped into the converter; the matte charge was poured upon this.[8]

The converting of copper in a Peirce-Smith converter is done

[6] *Nordisk tidende,* November 24, 1938. "Keller's report on basic linings in 1890 stated that they could not be employed successfully, because (a) basic material, being a good conductor, caused the outside of the converter to become too hot and the inside too cold; (b) such material broke up easily and so was unsuitable for use in permanent linings; and (c) even when basic linings were employed, the silica which was added as flux, refused to combine with the iron oxides. These views were very generally accepted for some years, until Baggaley's persistent efforts and finally those of Peirce and Smith showed that by perfecting the constructional methods and details, by preventing heat losses as much as possible, and by operating on very large masses of hot material, the above difficulties could all be overcome and the basic lining successfully employed"; Levy, *Modern Copper Smelting,* 202.

[7] Levy, *Modern Copper Smelting,* 202. For a more detailed account of the advantages of the Peirce-Smith converter, see H. O. Hofman, *Metallurgy of Copper,* 211–213 (New York, 1924).

[8] Levy, *Modern Copper Smelting,* 202. See also Hofman, *Metallurgy of Copper,* 211–213.

by forcing air through the tuyeres into the molten matte. Small streams of air pass through this, oxidizing the iron to iron oxide and the sulphur to sulphur dioxide, and at the same time giving a converting temperature of about 1200° C. The iron oxide then combines with the silica in the flux to form slag, while the sulphur dioxide passes off as gas. Heat is furnished by the oxidation of the iron and sulphur and by the formation of the iron-silicate slag. The copper, reduced to a metallic state, settles to the bottom of the vessel and is then cast into forms suitable for further treatment.[9]

The new converter naturally created great interest when it appeared. The *Engineering and Mining Journal,* to mention only one technical periodical, spoke of it as a new outgrowth, in a sense, of the steel industry—which it was—and emphasized that basic converting along orthodox copper lines was by no means untried when Smith went to work on it. This periodical described the first converter as a tilting reverberatory furnace, a large cylindrical shell with ends like the frustums of cones. From experience with this furnace a later type of converter was evolved. The new converters were improved by moving the mouth to the center and substituting pipe tuyeres, the number of which was increased to 37. Ordinary converters, it was explained, could easily be changed to the new method by the simple expedient of lining them with magnesia bricks—a procedure actually undertaken by Anaconda. The latest Peirce-Smith converter (in 1917) was described in detail. Tilted by an electric motor and capable of producing over 100 tons of blister copper while converting a 40 per cent matte, the new converter was in use at such important copper centers as Tacoma, Garfield, and El Paso, and was being installed at Hayden, Arizona, at the Braden Copper Company mines in Chile, and at the new plant of the British America Nickel Corporation in Sudbury, Ontario.[10]

One voice was raised to protest the honors given Cappelen

[9] Krejci, in *Engineering and Mining Journal,* 104:669–674.
[10] Vol. 91, p. 943, 964 (May 13, 1911); vol. 104, p. 674 (October 20, 1917).

Smith and Peirce, that of Ralph Baggaley, whose experiments with basic lining at Butte have already been mentioned. Baggaley not only questioned the originality of Smith's work, but claimed all credit for the new process for himself and even charged that Peirce and Cappelen Smith had merely subjected his discoveries to certain elaborate tests. Baggaley claimed that he had unwisely described his experiments to the Guggenheims. "What have Smith and Peirce invented or developed?" he asked. "I practiced the art [of basic lining] with perfect success for 8½ months, using a single lining, years before they even commenced to test the correctness of my theories and which theories all of their own experts disputed. As a well-known authority has stated to me, all of Smith and Peirce's patents for 'improvements' on my process are really 'steps backward.' Their design and construction are such that it is impossible to hold their linings or tuyeres in place." Baggaley then proceeded to detail the advantages of his own converter.[11] Authorities, however, are unanimous in crediting Smith and Peirce with the successful introduction of basic lining.

Their professional standing was strengthened by a severe test. The basic patents for the converter properly filed, the two men organized the Peirce-Smith Converter Company to manufacture the new product, with Smith as vice-president and director of the firm. Within two years every large copper company was using the new converter, but it occurred to none to pay royalties to the inventors. In this they were merely following tradition: no copper company in America had ever paid an inventor for the privilege of using his discoveries. In the case of the converter, however, they made a mistake. The Peirce-Smith Company decided upon a test case, patiently waited until the copper interests had installed their converters, and then began legal action against Senator W. A. Clark of Montana and his United Verde Copper Company. The result was a classic case in the history of the American patent system;[12] and the

[11] American Institute of Mining Engineers, *Transactions*, 46: 480–485.
[12] United Verde Copper Company *vs.* Peirce–Smith Converter Company (1923).

four volumes of testimony that resulted constitute a veritable textbook in metallurgy. Peirce and Smith were completely established as the inventors of the basic-lining process.[13] Senator Clark was less fortunate. The Peirce-Smith Converter Company had originally asked him for only $40,000; this request had been rejected. After the trial Clark's firm turned over $850,000 to the converter company.

III

Cappelen Smith's career, so brilliantly begun in the United States, was destined to continue on another continent—this time resulting in the invention and introduction of the extraction method in use at Chuquicamata, in Chile, the largest developed copper deposit in the world.

The problem of this remarkable mine was perhaps first brought to Smith's attention in the period 1910–12, when, as consulting metallurgist of the American Smelting and Refining Company, he also served as consultant to the Braden Copper Company, a Guggenheim firm in Chile. He visited South America for the first time in 1912. The Chuquicamata mine was acquired by the Guggenheims when Pope Yeatman, who had previously bought Braden and other low-grade copper mines for them, concluded that "Chuqui" could be made to yield millions if a satisfactory method of extracting the copper could be developed.

Chuquicamata lies north of Calama, a station on the railroad going up to Bolivia from Chile, between a coastal range of mountains and the Andes. Located in a desert region at an elevation of from 9,000 to 10,000 feet, it enjoys neither rain nor snow. Its ore deposits had been worked by the Indians long before the Spanish conquest. Later attempts to mine its copper,

[13] The patent under fire was number 943,280, filed in October, 1909, by Cappelen Smith alone. The Circuit Court of Appeals (Third Circuit), in reviewing the case, held that Smith was the "first to show that slag had two habits . . . innocent and vicious, and he was the first to show how one could be obtained and the other avoided, and, in consequence, how a basic lining could be preserved through greatly increased length of operation." The patent was held "not anticipated, valid, and infringed"; *Federal Reporter, Second Series,* vol. 7 (2d), November–December, 1925, p. 13–19 (St. Paul, 1926).

however, met with general failure. It came under Guggenheim control in 1911. Early the next year the Chile Exploration Company, with a capital of $1,000,000, was incorporated for the purpose of opening the mine. By 1913, exploratory work in which Cappelen Smith played a part revealed that there were at least 154,000,000 tons of ore at Chuquicamata, averaging about 2½ per cent copper. Actually the deposit is vastly greater.

The Chile Copper Company, with a capital of $110,000,000, was then organized to buy up the properties of the Chile Exploration Company. It is said that immense sums were invested in developing and equipping the property. Many unexpected difficulties arose, among them the fact that the ores were found to contain nitrates as well as chlorides and sulphates. The resulting technique involved both leaching and precipitation of the low-grade ore. Not only was it the first large-scale operation of its kind, but the Chuquicamata process involved a surprisingly low plant cost.[14]

The scientific studies that followed Yeatman's preliminary investigation of "Chuqui" ores were conducted under Cappelen Smith's leadership in the Guggenheim laboratories at Perth Amboy, New Jersey. Considerable money was spent in what is generally regarded as extremely clever research. The outcome was the chemical process already referred to, worked out to the last detail and requiring an elaborate set of equipment. A crushing plant, which would reduce the ore to one-half inch mesh, was built. The leaching plant called for six great tanks—each 150 feet long by 110 feet wide and 16 feet in depth. In addition, a pump house, an electrolytic tank house, and a smelting plant had to be provided. It was found, however, that the same results were obtained when the ore was treated in Chile on a 10,000-ton scale as in Perth Amboy with much smaller units.

The Smith process (it is more commonly known as the Gug-

[14] See H. Foster Bain and Thomas Thornton Read, *Ores and Industry in South America*, 221 (New York, 1934); A. B. Parsons, *The Porphyry Coppers*, 256–283 (New York, 1933); *Fortune*, 2: 72–76 (July, 1930). A good general account is Joseph Newton and Curtis L. Wilson, *Metallurgy of Copper*, 345–356 (New York, 1942).

genheim process) is logically suggested by Chuquicamata ore. The principal mineral in the ore is brochantite, a basic sulphate of copper easily soluble in sulphuric acid. Therefore, according to one writer, leaching with sulphuric acid "suggests itself at once." In the opinion of the same writer, "the electro-deposition of copper from this sulphate solution, thus producing fine copper at one step, presents itself as the most advantageous and feasible method of precipitation."[15] The crushed ore is leached with sulphuric acid. The greater part of the chlorine is eliminated by treatment in drums with metallic copper. The remaining copper is precipitated by electrolysis and the cathodes melted into commercial bars. Cuprous chloride, formed in the dechloridizing drums, is treated to recover copper either by smelting or dissolving the cuprous chloride with salt and then electrolyzing, or by treatment with metallic iron to form cement copper.[16]

But while in theory the process of dissolving the ore in cold acids and recovering the copper by electrolysis is relatively simple, the problems facing Cappelen Smith were innumerable. He had to develop, first of all, materials with which to make vats, pipes, and anodes in the electrolytic cells—where dissolved copper is precipitated as metal—that would withstand the action of acid solutions and at the same time have the necessary structural and electrical properties. For lining the concrete leaching vats as well as the cells, a solution composed of asphalt and silica sand, reinforced like concrete, was worked out. Many experiments were tried before a satisfactory material for the anodes was developed.[17] To these and many other technical problems must be added the fact that water for all purposes had to be brought by pipe line from sources 40 to 250 miles away. Long-distance transmission of power at 110,000 volts also presented difficulties.

[15] C. A. Rose, "Metallurgical Operations at the Chile Exploration Co.," in *Engineering and Mining Journal,* 101:321 (February 12, 1916).

[16] Pope Yeatman, "Mine of Chile Exploration Co., Chuquicamata, Chile," in *Engineering and Mining Journal,* 101:313 (February 12, 1916).

[17] Parsons, *The Porphyry Coppers,* 268–271.

The Chuquicamata plant began operating on a commercial scale May 19, 1915. It was soon found that in purity "Chuqui's" copper was somewhat higher than that from American electrolytic refineries. By 1929 the Guggenheim property was producing copper "at the rate of 400,000,000 pounds per year, at a cost of about six cents per pound delivered in Europe." [18] The immigrant engineer had thus successfully made his second great contribution to the American copper industry. In recognition of Smith's pioneer work at Chuquicamata, in 1920 he was awarded the gold medal of the Mining and Metallurgical Society of America — an honor bestowed on very few — for distinguished service in the art of hydrometallurgy.[19]

Proud as Smith is of this honor, he is more pleased with the growth of a thriving city of 25,000 at Chuquicamata. It may be questioned whether the mining activities of American and European firms have been an unmixed blessing to Chile, but one cannot doubt Cappelen Smith's sincerity when he describes the conditions now existing among the native workers at "Chuqui." In a strange world high above sea level, the workers enjoy warm clothing; company-built houses, hospitals, and schools minister to their physical and mental needs; and parks lend a touch of warm beauty to the city.[20]

IV

According to the magazine *Fortune*, Smith could not go from Antofagasta to Chuquicamata without crossing great nitrate pampas. "It was but natural," we learn, "that he should speculate on the possibility of translating the *cold acid* technique of Chuqui to a *cold water* technique for the nitrate field." [21] The same source suggests that he had "looked over the great ancient

[18] Bain and Read, *Ores and Industry in South America*, 222.

[19] Mention should be made of the fact that Cappelen Smith also planned and built a new smelting plant for the Braden Copper Company in southern Chile. The Braden mines and plant, handling a copper pyrite and producing commercial copper by the usual smelting and converting methods, constitute one of the largest copper units in the world. Cappelen Smith was consulting engineer and vice-president of Braden. See *Engineering and Mining Journal*, 101:315–321 (February 12, 1916).

[20] See *Nordisk tidende*, November 24, 1938.

[21] Vol. 2, p. 59 (October, 1930).

industry of the desert" and had studied the 150 "relatively small oficinas (nitrate extraction plants). They drilled holes and blasted the desert rock, scraped off the barren upper layer, and three or four feet beneath came on the rich nitrate-bearing *caliche*."[22] This caliche is a rock of ordinary appearance but nearly as hard as granite. Smith, brooding over the subject of nitrate, concluded that he could improve upon the technique then used—the Shanks method—for taking the nitrate from this rock, and in three years "the chemistry of nitrates was rewritten in New York laboratories." To test his theories, Smith built an experimental plant at Oficina Cecelia near Antofagasta "and in two years more demonstrated the feasibility of his idea." The Guggenheim brothers, by now thoroughly aroused, "gathered in their joint office at 120 Broadway and issued orders to buy nitrate fields."[23]

To understand why the Guggenheims were so vitally interested in Cappelen Smith's experimental work with Chilean nitrate, one must only keep in mind the competition in nitrates during peacetime. Necessary in modern warfare, Chilean nitrates sold for a good price during the First World War. In the years that followed the war, however, the market was dull, since their only other large use is in commercial fertilizers. Competition for the agricultural market was keen, and only low-cost nitrates had a chance.

The cost of producing nitrates had been greatly reduced by a revolutionary method introduced in the early years of the twentieth century. In Norway Professor Kristian Birkeland and Sam. Eyde, an engineer, succeeded in their attempt to fix atmospheric nitrogen. They developed a furnace in 1903 that was able to form nitrogen oxides by means of an electric spark.[24] As later improved, both in Norway and in Germany, the new method lowered costs considerably below those of the old method of producing Chilean nitrates.[25] The chief requirement of the

[22] *Fortune,* 6:66 (August, 1932).
[23] *Fortune,* 2:59 (October, 1930).
[24] Frank A. Ernst, *Fixation of Atmospheric Nitrogen,* 12 (New York, 1928).
[25] For an account of Chilean nitrates see J. R. Partington and L. H. Parker, *The Nitrogen Industry,* 33–84 (New York, 1923).

new process was an abundance of cheap power. The Chilean deposits were obviously doomed, unless Smith could find a process as revolutionary in its way as the Birkeland-Eyde process had been some years before.

The Guggenheims, in contemplating the results of Cappelen Smith's laboratory and plant experiments, perhaps reasoned in this manner: They had spent large sums on what had once been considered worthless copper properties. Smith's work had cost about $50,000,000, but the low-grade ore was made to pay handsome dividends. "A $50,000,000 hole in the ground became a $200,000,000 property and it was with some satisfaction that the Guggenheims pocketed their profits when they sold it to Anaconda in 1923."[26] The copper that came from "Chuqui" had also become a standard for purity. Now Smith's new process for treating the low-grade caliche promised returns at least as great as those in copper.

The Guggenheims therefore bought up nitrate-bearing desert areas in northern Chile. From the Chilean government they bought at auction a nitrate deposit at Coya Norte near Tocopilla; they then added the near-by lands held by the Anglo-Chilean Nitrate Company. The railroad to the coast was modernized and in 1924 the Anglo-Chilean Consolidated Nitrate Company was formed. Cappelen Smith was then instructed to build a modern nitrate plant. Debentures to the value of $16,500,000 were issued and Maria Elena, the new plant, "began to rise from the white desert." The problems were many. The Guggenheims had to put up additional funds totaling about $25,000,000. The plant's original capacity of 45,000 tons of nitrogen a year was eventually increased to 106,000 tons, or more than the United States bought from Chile in 1913.

Maria Elena was put into operation late in 1926. Its advantages when weighed against the Shanks process were obvious. The Lautaro Nitrate Company, Limited — a British firm — decided to avail itself of the new Smith technique and in 1929 gave the Guggenheims a half interest in exchange for a con-

[26] *Fortune*, 6:65 (August, 1932).

tract to build a plant similar to Maria Elena, but with a capacity of 132,000 tons of nitrogen a year. To pay for the plant Lautaro issued bonds to the amount of $32,000,000.[27]

James ("Don Santiago") Humberstone had worked out the method known as the Shanks process. This process, in use for some time before the Guggenheims interested themselves in Chilean nitrates, depended to a large extent upon hand labor, both in mining the caliche and in extracting the saltpeter. It also used hot solutions for extracting the nitrate from the ore, thus involving the use of much fuel. The tanks used were relatively small and the commercial product, only 96 per cent pure nitrate, came in the shape of irregular crystals.[28]

The Guggenheim process, by contrast, almost eliminated the workman. "From the mining of the caliche to the bagging of the nitrate the machine does all the work, the workman is necessary only to direct it." [29] The three feet or so of overburden, or costra, is removed by giant electric scrapers. The caliche, thus exposed, is "lifted" by blasts "utilizing as much as 7,000 pounds of black powder (made in the plant from nitrate of soda and charcoal) in a single shot, breaking up in a few seconds 10,000 tons of the ore." The pieces of rock are then picked up by electric shovels—half a ton or so at a time—and dropped into the cars of an electric train that runs to the extraction plant. Here they are tilted by mechanical power and their contents dumped into crushers capable of reducing 1,200 tons of caliche per hour. Boulders are "reduced to rocks, rocks to pebbles about the size of a California cherry." [30] Then, moving on a conveyor belt, the crushed ore is delivered to one of ten concrete leaching tanks where the nitrate is separated from the ore by lukewarm leaching solutions.

According to J. Enrique Zanetti, an authority on nitrates, it is at this point that Cappelen Smith's system proved its effec-

[27] *Fortune,* 6:66.
[28] J. Enrique Zanetti, *The Significance of Nitrogen,* 24–27 (New York, 1932); *Fortune,* 2:59 (October, 1930).
[29] Zanetti, *Significance of Nitrogen,* 24.
[30] *Fortune,* 2:60 (October, 1930).

tiveness. The solutions, when applied to the crushed caliche, are warm, as already stated; precipitation of nitrate is caused by cooling these warm solutions to about freezing temperatures. No direct fuel as a source of heat is necessary; waste heat is taken from the huge Diesel engines furnishing electric power to the plant. "The water which circulates around the cylinders of the Diesel motors is warmed sufficiently to heat the solution to the desired temperature. . . . Solutions coming to and from extraction tanks are passed through a system of heat interchanges where the solution that has been cooled takes up heat again from one that is going to be cooled, thus saving important amounts of fuel." The strong nitrate solutions from the leaching tanks flow to crystallizing tanks where the solution is cooled by means of a heat interchange with the cold returning solutions. The nitrate is separated from the solutions by means of centrifugal machines; when dry it is white and about 98.5 per cent pure. The solution from which the nitrate was crystallized—the mother liquor—is "warmed up again through heat interchangers and pumped back to a new extraction tank. The solution is then really acting as if it were a belt conveyor. It picks up nitrate from the caliche, deposits it in crystallizers and goes back again to begin its cycle."[31]

The nitrate coming from the crystallizing process is in the form of tiny crystals, not unlike table salt; in this form it greedily absorbs moisture from the air. It was found, in fact, to be "so finely divided, so thirsty that it . . . formed into white boulders the size and shape of the bags in which it was packed and practically impervious to the onslaught of crowbar or pickax." To prevent this, the crystals are melted at a high temperature in a shaft furnace and then "forced through a pipe which terminates in a fine spray cap. The scalding yellow liquid leaps high in the air, where it cools and forms into snow white beads that tumble back into the last conveyor, bound for the automatic weighing and sacking machines. These beads have a glaze which resists moisture and have a much more attractive

[31] Zanetti, *Significance of Nitrogen*, 25.

commercial appearance than that of the irregular crystal of the old Shanks product."[32] The spraying is done in large steel-plate towers kept cool by air circulation. The saltpeter is packed in bags weighing 100 or 200 pounds. The farmer can spread the pellets on fields either by hand or machine.

When the caliche is being reduced in the giant crushers a column of dust shoots skyward and is visible ten miles away. Over this part of the plant "hangs a pall of dust." According to Zanetti, this is one of the "inevitable nuisances of a nitrate plant. The fine dust, carried by the wind, settles over the entire plant, covering everything with a layer half an inch thick." In any place where there is oil or water a thick, hard crust forms.[33]

Fortune reveals that the production costs of the Smith process are 6 to 9 dollars less per ton than those of the Shanks method. Chilean nitrate sells at the same price as synthetic sodium nitrate, which was about 27 dollars F.O.B. cars at Atlantic seaports up to the beginning of World War II, and thus the economies of the new process have apparently permitted Chilean nitrate to maintain a competitive position with its equivalent synthetic product. Zanetti describes the Guggenheim process as "an outstanding achievement of modern chemical engineering," and a U. S. government publication states, "In Chile, the erection of the two Guggenheim plants [*Maria Elena and Pedro de Valdivia*] did not greatly enlarge the national capacity but probably prolonged for a number of years the ability of that country to compete effectively."[34]

The Smith process was not only superior technically to methods used elsewhere in Chile, but it also led to the establishment of a giant Chilean nitrate industry dominated by the Guggenheims. The story of this industry must be told by others,

[32] *Fortune,* 2:60 (October, 1930).
[33] *Significance of Nitrogen,* 26.
[34] United States Tariff Commission, *Chemical Nitrogen,* 5 (report no. 114, second series—Washington, 1937). For a further discussion of costs, see *Fortune,* 2:105 (October, 1930); Zanetti, *Significance of Nitrogen,* 27, 67; Harry A. Curtis, *The Nitrogen Situation,* 46–49 (Senate Document no. 88 — Washington, 1942); Ernst, *Fixation of Atmospheric Nitrogen,* 88.

but none can study the international competition in nitrates without being aware of its implications in "dollar diplomacy" and world imperialism. As a background to this drama, conferences of all nitrate interests were held during the summer months of 1930 at Paris, Berlin, and Ostend. Cappelen Smith attended as a representative of the Chilean producers, who were fully conscious of the effects of increasing tariff walls and the tendency of European nations to build up synthetic nitrogen plants. In 1931, on the insistence of the Chilean government and as a result of Smith's efforts, a consolidation of the Chilean nitrate industry resulted in the formation of the Nitrate Corporation of Chile, with Cappelen Smith as president. In 1934 this corporation was dissolved by a law declaring the export of nitrate a government monopoly.

V

In addition to his other work in metallurgy, Cappelen Smith has interested himself in the treatment of sewage and the elimination of smelter gases for the recovery of sulphur. He has been in charge of the research work connected with both projects. The first of these, because of its universal interest, seems to justify some space in this account.

Early in 1936 *Water and Sewerage Works* commented on a "novel method of chemical treatment" of sewage "first developed on a small scale in New York and later at New Britain, Conn." This biochemical process, the magazine observed, "appears to yield a very satisfactory effluent."[35] The story behind this new Guggenheim process is not so distantly removed from previous experience as it might at first seem to be. Smith's New York staff of researchers, naturally interested in nitrates, chanced upon an article titled "Nitrate Prevents Obnoxious Odors" in the September, 1931, issue of *Chemical and Metallurgical Engineering*. They began in 1934 to experiment with the effect of sodium nitrate (the Chilean product) on sewage

[35] Samuel A. Greeley, "A Review of Sewage Disposal in the United States at the Close of 1935," in vol. 83, p. 31–36 (February, 1936).

treatment and in a short time worked out what is known as the Guggenheim process.

The biochemical process was said to give excellent results in treating ordinary sewage. New Britain, Connecticut, however, was the first city of any size to install a treatment plant of this type. In the spring of 1935 the Guggenheim Brothers got the city's permission to set up a 100,000-gallon-per-day experimental station. A coagulant was there mixed with the sewage in air-agitation tanks from which most of the settled sludge was returned to the mixing tanks. The results proved the claims made for the system.[36] In 1936 New Britain then decided in favor of the new system to handle her industrial and domestic waste. By January, 1937, a plant "designed to treat nine million gallons of sewage daily was ready to be put into operation. The plant . . . consists of coarse bar screens, primary settling tanks, dosing tanks, aeration tanks, final settling tanks, vacuum filters and a multi-hearth furnace. There also were provided adequate chemical feed machines and standard auxiliary equipment." After the first difficulties met in breaking in the plant, it worked very well. Because of the flexibility of the process, its ability to withstand sudden shocks of industrial waste, much time and money were saved by the Guggenheim process. "The results for the first five months of 1939 . . . speak for themselves. With monthly flows as high as 40% over designed capacity of the plant, the overall reduction in suspended solids and B.O.D. averaged 91% for this period."[37]

Anderson, Indiana, like many another city, had been dumping raw sewage and untreated trade wastes into the White River. In November, 1938, contracts were let for a modern treating plant of the Guggenheim type. Commenting on this decision, Russel B. Moore says, "It is not the writer's purpose to convey the impression that the Guggenheim Process can be considered a panacea for all sanitary ills, but we do feel that in

[36] F. G. Cunningham and H. K. Gatley, "New Britain Completes Plant of Guggenheim Type," in *Municipal Sanitation*, 8:214–220 (April, 1937).

[37] John R. Szymanski, "Bettering the Treatment of the Sewage of New Britain, Conn.," in *Water and Sewerage Works*, 86:315–319 (August, 1939).

the case of Anderson the adaptation of biochemical treatment is definitely the best solution to the problem."[38]

VI

Less spectacular perhaps, but of far-reaching importance in New World nickel production, has been the work of Anton M. Grønningsæter, consultant with the Falconbridge Nickel Mines, Limited, of Toronto, Canada. The fruit of Grønningsæter's work in Norway was used by the Nazi invaders to supply their war machine. During World War II he did all in his power to enable Canadian mines, supplying 90 per cent of the world's nickel, to contribute their share to ultimate Allied victory.

Grønningsæter was born at Hjørundfjord, Søndmør, in 1880, the son of a *lensmand.* He attended Trondhjem's Technical College during 1896–1900, graduating with a degree in chemistry. After two years as an instructor at his alma mater, he improved his technical education by a year of study at the Royal Bergakademie at Freiberg, in Saxony, Germany. Returning to Trondhjem, he served a second period as instructor in the technical college and afterwards obtained practical experience in the copper smelter at Sulitjelma. Later he thus described the state of metallurgy in Norway (and the world) in 1904, before the epoch-making contributions of Cappelen Smith: "Our water-jacket furnaces had a capacity of 50–60 tons daily, we charged by shovel on 12 hour shifts, so many shovels of ore, so many of flux, so many of coke; the acid-lined copper converters had a capacity of 1500 lbs. per charge and were moved by hand on rails from the stand to the settler for charging with matte. The pay was 8 cents an hour."[39]

Like many another young engineer before him, Grønningsæter was dissatisfied with the wages and technical opportunities of the homeland and came to the United States — armed with letters of introduction — to get experience in his profession

[38] "Bio-chemical Treatment for Anderson, Ind.," in *Water and Sewerage Works,* 85: 1029–1034 (November, 1938).

[39] From a lecture delivered in 1941 to fourth-year students of mining and metallurgy at Toronto University. A copy of this lecture was put at the writer's disposal by Grønningsæter.

that would later stand him in good stead in Norway. Arriving in New York early in 1905, he found work at once as chemist with the International Nickel Company, at Bayonne, New Jersey; in the same year he went to the Sudbury nickel mines in Ontario.

Sudbury, the very heart of the nickel industry, lies in what was then a desolate region some miles north of Lake Huron. The raw ugliness of the little town of between two and three thousand inhabitants, with its thirty or forty saloons, must have impressed Grønningsæter greatly, for he dwelt on the subject years later in a newspaper interview.[40] Dependent upon the nickel and lumbering industries, the town witnessed strange goings-on when the workers came in with pay in their pockets. Sudbury today is an orderly and up-to-date city of about 35,000 inhabitants. In 1905, however, the young engineer found little that was attractive, and the intense cold and long winters made the experience a rather trying one. The nickel industry in Sudbury was then about twenty years old and the vast deposits of ore were considered inexhaustible.

For four years Grønningsæter worked in the smelters and refineries of Canada, but in 1909 he returned to Norway to begin a notable project in his homeland. Invited by the promoter, Admiral Børresen, he took a vigorous part in building the Christiansand Nickel Refining Company's plant, and this refinery he directed for the next ten years. This company, with Admiral Børresen as administrative director, was a purely Norwegian concern and at first produced about 300 tons of nickel a year. The ores came only from Norwegian mines, chiefly from Evje, and the undertaking was therefore necessarily a modest one. Production at best never surpassed an annual output of 800 tons, and employment did not exceed about 100 men.[41] A stimulus of some kind was needed.

During the First World War the Norwegian company became interested in Canadian nickel output and the British

[40] *Fædrelandsvennen* (Christiansand), October 20, 1939.
[41] See Reidar Lund, "En fremragende industriell innsats," in *Teknisk ukeblad,* no. 9, p. 139 (March 1, 1934).

America Nickel Corporation of Ottawa, Ontario, was accordingly organized. Grønningsæter went to Canada in 1919 to help start the new company's mine, smelter, and refinery in the Sudbury district. His connection with this company was severed in 1924 when the firm went bankrupt, largely because of the letdown in nickel production that followed the war. For some years he held jobs in the United States, including a temporary employment with Victor N. Hybinette at Wilmington, Delaware. Hybinette, a great Swedish engineer, introduced the basic principles today used in the electrolysis of nickel matte, a method which accounts for about 70 per cent of all nickel produced. His methods had also been introduced in the Christiansand refinery in 1910.

In 1927 Grønningsæter became consulting metallurgist for Falconbridge Nickel Mines, Limited, of Toronto, the firm with which he is still associated. This company in 1929 bought the refinery at Christiansand, largely on the advice of its new engineer. It may seem strange that they should have made an investment in Norway; in fact, for some time Falconbridge had contemplated building a refinery in Canada. After reflection, however, it was decided to acquire, remodel, and enlarge the Christiansand plant. After years of careful study and application, the newly acquired plant was made to produce nearly one tenth of the world's supply of nickel. From 2,500 tons annual output in 1929, production gradually climbed to 10,000 tons.

Falconbridge bought only the Christiansand refinery, the mines and smelter remaining with the Norwegian company. The refinery was planned for a novel system of production which drew from mines on both sides of the Atlantic, since Norwegian ores alone did not permit the economies of large-scale production. Up to the time of the Nazi invasion of Norway, Canada supplied the Christiansand refinery with many times the amount of raw material that Norway did. In the reorganization and management of this refinery Grønningsæter was the leading figure, and under his direction began an inter-

esting experiment in co-operation between the Old World and the New.[42]

Grønningsæter's metallurgical work in Norway centered in perfecting production techniques and getting a steadily improved quality of nickel. These two objectives have remained with him to the present in his work on both sides of the Atlantic.

Production in Norway presented the problem common to all small countries with limited resources. Unable to compete with the mass-production methods of countries like the United States, they must concentrate on quality. A good example of this is the iron and steel industry of Sweden.[43] Nickel production offered the same difficulties. Grønningsæter's success in meeting these difficulties is described by another Norwegian engineer. Writing in *Teknisk ukeblad,* Reidar Lund explains that, "Mr. Grønningsæter . . . saw that with the help of cheap Norwegian water power and skilled Norwegian workers and staff he could turn out nickel cheaper in Norway than in Canada. . . . Expansion and modernization were immediately undertaken at the Christiansand plant . . . and the results were so encouraging that new enlargements were introduced in 1932–33." This rapid development was also accompanied by steady improvement in the quality of nickel. "Not so long ago, one struggled with impurities determined and specified in the order of one tenth to one hundredth of one per cent. Today only pure metal is acceptable, that is to say, high quality products, where impurities are determined and specified in the order of thousandths of one per cent. . . . Mr. Grønningsæter's work is of the finest and most notable that has been accomplished in Norwegian industry in recent years and it deserves to be generally known and esteemed."[44] In recognition of his work the Norwegian Polytechnic Society in 1937 awarded him

[42] This section is based largely on the exceedingly competent review of Grønningsæter's career in *Fædrelandsvenner,* October 20, 1939, and on information obtained from Grønningsæter.

[43] See Grønningsæter, "En oversikt over elektrometallurgiens nuværende stilling med spesielt henblikk på norske forhold," in *Teknisk ukeblad,* no. 10, p. 3 (1936).

[44] *Teknisk ukeblad,* no. 9, p. 139 (March 1, 1934).

its highly valued Sam. Eyde prize, and in the same year he was elected to Videnskapsselskapet in Oslo, a learned scientific group.

VII

If it may be said that Grønningsæter introduced American production techniques in Norway, it is also true that he carried with him to the New World the point of view of the Old. His contribution to the metallurgy of nickel includes the lowering of metal losses.

The need for this would seem to require little emphasis today, but Grønningsæter recently found it necessary to remind the Sudbury branch of the Canadian Institute of Mining and Metallurgy that "ores do not grow within historical periods—although our forefathers thought so. No matter how great the supply of mineral wealth in Canada now seems to be, it is certainly not inexhaustible. In the older countries, where mining is an important industry, this fact has been realized for many years, and steps have been taken to conserve supplies. The same must be done here."[45] Speaking to the seniors in mining and metallurgy at the University of Toronto, he said: "Lessening of waste has been an important factor . . . during the period I have been considering. . . . Lower grade ores have been mined. But there is room for much more improvement in this line and I wish to stress the importance of this. I think we old country people, who have been raised in old, more worked out countries, have a stronger feeling of the importance of this, than you who have been raised on this continent, where you yet, to a considerable extent are occupied with skimming the cream. Sooner than imagined you will come down to the blue milk. . . . I think the time has now come that in the metal business the principle should be to save everything that can be saved at a profit, be this profit ever so small."[46]

The pertinence of these words becomes apparent when it is

[45] *Sudbury* (Ontario) *Daily Star,* March 4, 1941.

[46] From a lecture delivered in 1911; a copy was put at the writer's disposal by Grønningsæter.

recalled that most of the world's nickel is obtained from the Sudbury field. The ores are copper-nickel sulphides containing cobalt, iron, and precious metals; they are smelted to low-grade mattes which are then blown in basic converters of the Peirce-Smith type for the removal of iron. The product of the converters — Bessemer matte — is shipped to nickel refineries where the process employed is a combined thermal and electrolytic one.[47] The method of extracting nickel and other metals from the ore had not escaped criticism. Robert E. Vivian said some years ago, "Although improvements have been made, the accepted processes so far have all slagged off and wasted the iron, comprising 90% of the metal content of the ore; they have lost 10–15% of the copper and nickel, and higher percentages of the precious metals, and have made use of crude processes for the separation of the copper from the nickel in the matte produced."[48]

The need for waste elimination increases with the normal increase in demand for nickel. Once used mainly for armor plate and ordnance, nickel's chief use today normally has nothing to do with war. Because it lends great strength, hardness, and resistance to corrosion, it is an important ingredient in ferrous alloys. Most stainless steels and irons contain considerable nickel. It is also used in Monel metal, coins, and many other alloys. Such industrial products as motor vehicles, railroad equipment, farm implements, common machinery, chromium plating, sheets, wires, radio tubes, and a host of other items use nickel. Because of the increasing strains and stresses of modern industrial life, the demand is constant for a higher quality nickel.[49]

The development of a better grade of nickel has taken place without any rise in metal price, thanks to improved metallurgical and other processes. According to Grønningsæter: "It is to

[47] C. L. Mantell, *Industrial Electrochemistry*, 259–267 (New York, 1940).
[48] *A Chemical Engineering Study of Sudbury Ore Processes*, 9 (New York, 1932).
[49] Vivian, *Sudbury Ore Processes*, 7. See also Robert C. Stanley, *Nickel, Past and Present* (Toronto, 1934), a reprint of a speech by the president of the International Nickel Company of Canada.

be expected that the present trend of demanding purer and purer metals will continue. . . . As the physical testing methods continue to improve, the demands for purity will keep step and become stricter and stricter. . . . It is probable that many of the consumers will only be satisfied with almost chemically pure metals, even if the impurities for many purposes may be harmless, or even useful alloying elements. . . . Accurate determinations of impurities down to 0.001% in metals and as low as 0.1 milligrams per liter in solutions is now regular laboratory routine. . . . We can perhaps say that the change that has taken place in the laboratory since the turn of the century is that the demand for accuracy has been moved one decimal point. . . . We now talk in figures instead of in trends, we work on a quantitative instead of a qualitative basis." [50]

Throughout this entire development in the metallurgy of nickel Grønningsæter has been a leader. It is difficult at any time to place a finger on precise scientific contributions, many of which never materialize in patented processes. But a glance at Grønningsæter's American letters patent tells a part of the story of his work. One describes a process for treating nickel-copper solutions to remove iron. Another has to do with the reduction of oxygenous nickel or nickel-copper compounds. A third and a fourth tell of methods for the electrolytic deposition of nickel from nickel-salt solutions. Still another describes a method for the production of malleable and annealable nickel direct by electrolysis, thus eliminating the resmelting common to electrolytic metal refining. A sixth "relates to the treatment of nickel cathodes obtained by electrolytic deposition and has for its object certain improvements in the method of treating the electrolytically deposited cathodes whereby their solubility characteristics particularly are so greatly improved that the cathodes may be directly used as anodes in nickel plating baths." In all he has eight patents in this country and more in

[50] From a speech, "Some Features in the Progress of Metallurgy from the Beginning of the Century," before Norske Videnskaps-Akademie (Oslo), September, 1938. A copy of this speech was put at the writer's disposal by Grønningsæter.

Canada and Europe. Pending in the United States are two applications, one for the purification of nickel electrolytes and another for malleable and annealable nickel. He plans to file at least one more application. A paper read before the Canadian Institute of Mining and Metallurgy brings out the "possibilities of obtaining appreciable economic advantages by *using the converter as a smelting machine*. When all factors entering into converter operations are studied, understood and given proper consideration, I believe that it will be found that there is more flexibility possible in operation to meet varying conditions than generally has been assumed." [51] As he himself has modestly put it, Grønningsæter has "made a number of improvements of details in the metallurgy of nickel."

During World War II Grønningsæter lived in Canada and New York. Though prevented by the German invasion of Norway from taking part in the work of the Falconbridge plant at Christiansand, until World War II he spent much time in that city. It was his conviction in 1936 that this nickel refinery would soon turn out 10 per cent of the world's supply.[52] The Nazi seizure of the plant, so largely the product of Grønningsæter's planning, naturally came as a great shock and disappointment to a man who might truly be called an internationalist, both in his personal life and in his professional attitudes. Since 1929 he has sailed back and forth across the Atlantic no less than 53 times. A citizen of the United States, he is married to a Canadian and has always felt most at home in Norway. Sensing the futility and stupidity of nationalism in economic life, he deplored the trend toward national self-sufficiency in the post-World War I period.[53] Like Cappelen Smith, he is engaged in a work requiring international co-operation and good faith among nations.

[51] Anton Grønningsæter and Peter R. Drummond, "Notes on the Operation of the Basic Copper (and Copper–Nickel) Converter," in Canadian Institute of Mining and Metallurgy, *Transactions*, 45:99–139 (1942).

[52] *Teknisk ukeblad,* no. 10, p. 3 (1936): "En oversikt over electrometallurgiens nuværende stilling med spesielt henblikk på norske forhold."

[53] *Teknisk ukeblad,* no. 10, p. 6; see also his article "Teknisk gjestfrihet," in *Teknisk ukeblad,* 84:162 (April 1, 1937).

VIII

The number of engineers specializing in metallurgy in recent times has been considerable, and of the graduates from Norway's technical schools many have made solid contributions to American industry. Among the earliest to arrive in this country was Eystein Berg, on a special mission to erect a synthetic nitrogen plant—the first of its kind in America—in South Carolina. Berg, a close associate of Sam. Eyde in Norway, was also credited with planning the American Nitrogen Products Company at Seattle.[54] Otto H. Lorange, who came to the United States in 1901, made a specialty of manufacturing ferro alloys with the Primus Chemical Company: ferro-tungsten, ferro-vanadium, and ferro-molybdenum. Later he became superintendent of the United States Vanadium Corporation in Ohio.[55] Trygve Yensen, another to migrate in the early years of the present century, introduced a novel method of processing electrolytically-refined iron and thus influenced the production of steel.[56]

Of more recent importance has been the work of Haakon Styri, who at present is director of research for the SKF Industries at Philadelphia, a part of the great Swedish ball-bearing cartel. In 1910 Styri spent a year studying at the Carnegie Institute of Technology under the auspices of the American-Scandinavian Foundation. He came to the United States to stay in 1916, after having served as chemist at the Notodden saltpeter plant in Norway and as instructor in the Institute of Technology at Trondhjem. Educated at Christiania's Technical College, the Technical Institute at Aachen, and the Sorbonne in Paris, Styri has also traveled extensively in France, Germany, Belgium, and Sweden, studying metallurgical practices.

Styri planned to contribute to the growing iron industry in Norway, but with the entrance of the United States into the

[54] *Washington posten* (Seattle), December 1, 1916.
[55] *Norwegian-American Technical Journal,* vol. 3, no. 2, p. 10 (August, 1930).
[56] *Ugens nyt* (Christiania), January 22, 1916.

First World War, he remained in America, served on the faculty of the Carnegie Institute, and worked as a metallurgist for a Pennsylvania steel company. In 1919 he was invited to become laboratory chief of SKF Industries, and since 1927 he has been director of all research for them. Author of several improvements in the refining of steel for tools and ball bearings, he also has patents on special steels and on the heat treatment of steel that have improved the quality of SKF products, though he modestly insists that his contributions are "of minor importance." Perhaps his most significant work has been directing research on the properties of anti-friction bearings and their uses in industry. His papers and discussions appear frequently in the publications of the British Iron and Steel Institute, the American Institute of Mining and Metallurgical Engineers, the Society for Testing Materials, and other similar groups.[57]

Axel G. H. Andersen, metallurgical engineer with the research laboratory of the Phelps Dodge Corporation in New York State, has done significant work on strategic alloys, and has published a part and withheld other parts of the results of his investigations. Educated at the Copenhagen Polytechnic Institute and the Massachusetts Institute of Technology, Andersen has conducted special research studies at Columbia University for Union Carbide. Most of his contributions to the *Transactions* of the American Society of Metals, the American Institute of Mining and Metallurgical Engineers, and the American Society of Mechanical Engineers have been jointly written with Professor Erick R. Jette of Columbia University. In 1937 the two men received Henry Marion Howe medals for their paper "X-Ray Investigation of the Iron-Chromium-Silicon Phase Diagram," presented before the American Society of Metals.[58]

Among others whose work has attracted the attention of engineers and businessmen is Birger H. Strøm, a graduate of the Norwegian Institute of Technology at Trondhjem. Leaving the

[57] Most of this information was supplied by Styri. See *Who's Who in America*, 17:2221 (Chicago, 1932–33).

[58] American Society of Metals, *Transactions*, 24:375–418 (1936). See also *Nordisk tidende*, October 26, 1939.

nickel refinery at Christiansand in 1919, Strøm went to Ottawa, Canada, to take a position with the British America Nickel Corporation. When this company closed down, he left to hold various positions in the States. While employed by the Anaconda Copper Mining Company at Great Falls, Montana, he collaborated in a number of improvements in the commercial process of electrolyzing zinc, helped work out the first commercially applied process for the recovery and electrolysis of cadmium in the United States, and also took the first steps in the discovery and removal of germanium in zinc solutions. During this period he participated in the development and design of zinc plants abroad—at Eitrheim in Norway, Cotrone in Italy, and Katowitz in Poland. In 1929 Strøm became assistant editor of the *Engineering and Mining Journal* and *Chemical-Metallurgical Engineering* at McGraw-Hill Publishing Company in New York. At present he is technical editor in the publicity department of the Bethlehem Steel Company.

Bjørn Andersen, now technical director of the Celluloid Corporation of Newark, New Jersey, also received his technical education at the Norwegian Institute of Technology, where he remained for a time as chief chemist in the testing department. Setting out for America in 1924, he found employment with Guggenheim Brothers as assistant manager of their research laboratory; while associated with Smith, Andersen was responsible for a new process of recovering tin from Bolivian tin concentrates, another for the recovery of bismuth from South American ores, and a new electrolytic process for recovering tin from reduced tin ores. Transferring to the Celluloid Corporation in 1928, he progressed from research chemist to assistant technical director, to director of research, and finally to his present position as technical director. He holds a couple of dozen patents for new processes in the production of cellulosic plastics, a field which he has made a specialty.

A third graduate of Norway's Institute, Arne J. Myhren, came to the United States in 1924 to obtain industrial experience, and remained to hold several positions, among them one

as research chemist in the Guggenheim laboratories. At present he is chief of the chemical engineering section of the New Jersey Zinc Company at Palmerton, Pennsylvania, and he has patented some of his many contributions in hydrometallurgy and chemical engineering. Odd Lowzow, after completing the metallurgical engineering course at Trondhjem, served for a year in the offices of an Oslo firm and then joined the police force of the League of Nations at Vilna. Finding himself without a job in 1921, he came to America and eventually became construction engineer with the Chemical Construction Corporation of New York City.

Representative of a number of engineers who have contributed to metallurgy, although their training has been primarily in other lines, is Torleif K. Holmen. Educated in the technical schools of Porsgrund and Mittweida and associated in America with such firms as the American Sugar Refinery Company and the Brooklyn Edison Company, Holmen is credited with the invention of a process by which magnesium is produced by the waste heat in nitrogen production. It is believed that his process will have special significance in Norway, where abundant and cheap water power is utilized in the production of nitrates.

Our story of the younger metallurgists closes with the brilliant career of Robert Lepsoe, director of electrochemical research with the Consolidated Mining and Smelting Company of Canada, at Trail, British Columbia. A product of both Bergen's Technical College and Norway's Institute of Technology, Lepsoe came to the United States as a fellow of the American-Scandinavian Foundation in 1920, with a technical background acquired in Norway's budding metallurgical industry. He came for the specific purpose of studying the electrolytic zinc process which had just been successfully developed in the New World; in 1921 he also visited metallurgical plants in France, Belgium, and Germany. Upon his return to Norway, Lepsoe advocated the use of the new process as the basis of the zinc industry in his homeland, but the firm with which he be-

came associated could not finance the undertaking alone.[59] Although Lepsoe was awarded a medal by the Norwegian Polytechnic Society in 1923 for a thesis on the zinc industry, and also received the backing of the Institute of Technology, which offered the financial means to demonstrate the new method, he was unable to interest the leading industrialists and bankers of the country. So when he was invited to join the Consolidated Mining and Smelting Company, which has one of the world's largest nonferrous smelters, he accepted and left for Canada in 1925.

As research engineer in British Columbia, Lepsoe blazed a remarkable technical trail. His patents, beginning as early as 1916, include such items as a process for ferro alloys, the electric smelting of copper, the production of zinc oxide, the production of zinc and zinc dust, the recovery of zinc, lead, silver, and iron from waste residues, the production of elemental sulphur and ammonium sulphate or sulphuric acid from smelter gases, the production of catalytic material and of magnesium from magnesite or dolomite. All of his processes found their way into commercial or semi-commercial use. Thus far perhaps the most important group of patents have been those dealing with the fixation of noxious sulphurous gases. Such gases are liberated into the air from metallurgical and power plants and are highly toxic to vegetation. In the past they have caused many litigations, among which the trial U.S.A. (in behalf of Stevens County, Washington) *vs.* Canada (Consolidated Mining and Smelting Company) was the most noteworthy. Apart from the elimination of smoke nuisance, Lepsoe's researches led to the recovery of large quantities of useful products such as sulphur, sulphuric acid, and ammonium sulphate.

Next in importance was his magnesium process, developed recently on a semi-commercial scale pending an increased demand for the metal. When Lepsoe developed the process there was only one producer of magnesium in North America—the

[59] Norway already had a zinc industry. A large smelter, for example, had been in operation at Sarpsborg since early in the First World War.

Dow Chemical Company of Midland, Michigan, which had exacted a monopoly. The Dow process was not only expensive but its raw material, brine, is limited. When the demand for magnesium grows to a point greater than can be supplied from the Midland brine well, other sources, notably magnesite, of which there are large deposits in Washington and British Columbia, will be utilized. The Lepsoe method was developed specifically for this eventuality, and it was anticipated that production costs would be less than at Midland, possibly less than for aluminum. The recent war called for extensive utilization of Lepsoe's process.[60] Canada has shown its gratitude for the contributions of the Norwegian engineer; the Royal Canadian Institute of Mining and Metallurgy in 1938 awarded him a medal for "distinguished service to Canadian industry." [61]

Thus the younger metallurgists, most of them graduates of Norway's Institute of Technology, are supplementing the work of men like Cappelen Smith and Grønningsæter. Coming from a small country vitally conscious of the value of its mineral resources and skilled in exploiting them, these men have concentrated on the utilization of mineral wastes; at the same time their careers have demonstrated the international nature of technology and industry. They have learned much in the New World and have used this information to promote the metallurgy of the homeland. But they have also taught priceless lessons to America and applied their skills to a development whose full significance is not yet fully evident.

[60] The writer has recently discovered that from 1941 Lepsoe's firm successfully produced magnesium powder for the Canadian and Allied governments, including the United States. The "atomized" magnesium which Lepsoe assisted in perfecting is made at surprisingly low cost by a new process; it was used in flares and tracers. As for Lepsoe's earlier magnesium process, this too was put to good use in the war years when shortages of magnesium metal and fluxes called for rapid production. The process employed at Trail was studied by American engineers during the period of expanded output in the United States.

[61] See *Nordmanns-forbundet,* 30:46 (1937) and 31:162 (1938). The discussion above was based chiefly on materials supplied by Lepsoe.

PUTTING SCIENCE INTO PRODUCTION

NO less important than the activities of the inventors, builders, and metallurgists is the story of Carl G. Barth's pioneer work with Frederick W. Taylor in the development of scientific management. It was this movement that revolutionized production in America and elsewhere by substituting science for the rule-of-thumb methods that once prevailed generally in our industries. While Barth is the major character in this story, he is supported by other engineers from Norway who added their bit to one of the most significant trends in recent times.

I

Scientific management consists of applying the results of careful study and observation to industrial production, and thus of setting up a division between management on the one hand and labor on the other. It has been defined as "a body of theory and practice directed toward more rational and efficient performance in industry. While it was used originally with reference to direct efforts to increase the productivity of labor, the application of the term has since been extended to include the basic factors in the process of production as a whole." The fundamental characteristic of scientific management is "the utilization of research as an approach to the solution of problems of management."[1]

The origin of the new management movement, however, is not so easily stated. It began, in a sense, in the early 1880's when a new technology made itself felt in American production; railroad extension and the westward movement of the frontier

[1] H. S. Person, "Scientific Management," in *Encyclopaedia of the Social Sciences*, 13:603 (New York, 1934). By permission of the Macmillan Company, publishers.

created new markets; new markets led in turn to the enlargement and mechanization of plants. The labor situation was unsatisfactory because of difficulty in adapting labor, both native and immigrant, to machine techniques. As a final incentive, the depression following the panic of 1873 lessened profits and necessitated the lowest possible unit cost of production.[2] One writer suggests that scientific management was a response to the requirements of the second stage in the American industrial revolution, which became pronounced about 1880—a time "when productive capacity began distinctly to outrun the capacity of the market to absorb goods at profitable prices. . . . Increasing limitations of the market now made imperative a more efficient use of productive equipment to cut costs and raise profits."[3] Two major causes thus emerge: the full impact of the industrial revolution upon American life and the need for lowering the unit cost of production.

But such scientific management as existed before 1910 was undefined and the concern of a few engineers only, and it cut no great figure in our economic life. Before that date it was the almost exclusive concern of the father of the movement, Frederick Winslow Taylor, and a zealous coterie of his assistants. Taylor began his experiments in 1880 but did not deliver his epoch-making address, "The Principles of Scientific Management," until the January, 1910, meeting of the American Society of Mechanical Engineers.[4] This address, printed in book form, created a sensation rarely accorded a speech before an engineering society.[5]

Taylor himself linked scientific management with the national conservation program that was popularized in the early

[2] Person, in *Encyclopaedia of the Social Sciences,* 13:603.

[3] Willard E. Atkins, "Taylor, Frederick Winslow (1856–1915)," in *Encyclopaedia of the Social Sciences,* 14:542 (New York, 1934). By permission of the Macmillan Company, publishers.

[4] Mention should, however, be made of three earlier papers which laid the foundations for this discussion: "A Piece-Rate System," presented in 1895; "Shop Management," read in 1903; and "The Art of Cutting Metals," presented in 1906, all before the American Society of Mechanical Engineers.

[5] This discussion is based on a special edition of Taylor's *Principles of Scientific Management,* printed for confidential circulation among engineers (New York, 1911).

years of the present century by Theodore Roosevelt, and in the preface of his book he quoted the president's statement, "The conservation of our national resources is only preliminary to the larger question of national efficiency." Thus Taylor's plea was for efficiency in the largest possible sense, and he argued that the remedy for inefficiency "lies in systematic management, rather than in searching for some unusual or extraordinary man," and that the best management of production "is a true science resting upon clearly defined laws, rules, and principles, as a foundation" applicable to "all kinds of human activities, from our simplest individual acts to the work of our great corporations, which call for the most elaborate cooperation." [6] The four major principles of scientific management, as defined by Taylor, are:

> First. The development of a true science.
> Second. The scientific selection of the workman.
> Third. His scientific education and development.
> Fourth. Intimate friendly cooperation between the management and the men.[7]

These, then, are the principles of scientific management. But Taylor, the author of the movement, was also responsible for accumulating a great body of data and formulating laws, chiefly but not solely in the art of cutting metals, and for devising mechanisms essential to the introduction of his principles into any plant. Carl G. Barth, an immigrant Norwegian engineer, "had as much to do with the details of development, testing and perfection of mechanisms as Taylor himself"; the Taylor technique remains to this day "essentially as these two developed it." [8] Barth, who was a scientist by nature and a practical mathematician, became after Taylor's death the leading exponent of the Taylor system. In retrospect his role seems to be of more than the minor importance often attributed to him by those students of the movement who ignore the technical skills

[6] Taylor, *Principles*, 7.
[7] Taylor, *Principles*, 69.
[8] Person, in *Encyclopaedia of the Social Sciences*, 13:607. By permission of the Macmillan Company, publishers.

without which the Taylor system of scientific management would have been impossible.[9]

II

Carl George Lange Barth was born in Christiania, February 28, 1860. His father, Jacob Bøckmann Barth, was Norway's "first technically educated and professionally devoted and respected forester," as well as a Unitarian with a sharp penchant for criticizing the religious and educational systems of his country.[10] At the age of twelve Carl was taken by an older friend to see a small brass foundry and machine shop. The young boy said that he was "so fascinated with the manner in which the chips were made to fly from the candle sticks being turned up under the skillful manipulation of a hand tool, that I then and there decided that I wanted to work in a machine shop when I got through school." His father had earlier insisted that Carl prepare himself for a professional education at the national university in Christiania; to that end, much to his disgust, he had been forced to study Latin instead of English. But instead of finishing the last three years of his preparation for the university, he was permitted, because of his interest in machinery, to enter the technical school at Horten.

Barth completed the short course in 1877, and went to work the same year in a boiler shop of the navy yard at Horten; this was the beginning of "what was to be a five year practical apprenticeship that was offered to a limited number of civilian graduates of the school." He spent nine months in the shop, first as a blacksmith's helper, "or until I had learned to produce

[9] It must also be borne in mind that much of the work for which Taylor, as leader, received credit was actually the product of Barth's genius. The latter speaks of this in several of his articles and Taylor intended before his death to make public his indebtedness to Barth, particularly in the matter of mathematical formulas. Among Barth's papers is an interesting document entitled "Preliminary Notes by Taylor for 'The Art of Cutting Metals,' which proves that most of the work was done by Carl G. Barth."

[10] See *Norsk biografisk leksikon,* 1:383–387 (Christiania, 1923). The account of Carl Barth is largely based on an unpublished story of his early life that he wrote for his children about 1927. Other general accounts of Barth's career are found in the publications of Horten's Technical School; *Who's Who in America,* 17:255 (Chicago, 1932–33); *Who's Who in Engineering,* 70 (New York, 1937); Magnus Bjørndal, in *Nordisk tidende,* November 30, 1939.

the helper's part of that to me fascinating music on the anvil that the old world blacksmith . . . produced in those days." At this early age his mathematical skill, later the marvel of his engineer associates, was useful enough in performing simple calculations "far beyond even the foreman's ability," and this ability naturally won praise from superiors and fellow workers alike.

Barth, next sent to the machine shop and detailed to run a small lathe, satisfied for the first time in his life his desire "to make the chips fly" and he enthusiastically recalls the "joy that was mine at the end of the days on which I turned more bolts than my buddy on the lathe next to mine." Next he was transferred to a little slotter "whose automatic feed had long been broken and never repaired." Barth persisted in requesting that the machine be repaired. One day while working on a special job he "set to work to experiment until I produced a tool that did what I was looking for." Even the oldest slotter operator had to admit that it worked. Barth drew the inevitable moral: "You will thus see that I commenced early in my career . . . to care but little for traditional ways."

When Barth was about to be transferred to yet another job, the assistant instructor of mathematics at the technical school quit his position. Barth was asked to give up his apprenticeship work to fill the vacated position, and he accepted. His new work as instructor filled the morning hours only; afternoons were spent in the office of the superintendent of the shops. Barth tells us that he only reluctantly gave up his "proud career of chip producer, not to return to it until I twenty years later joined Mr. Taylor at Bethlehem and soon became the world's champion and only scientific chip producer of that growth-making period of the machine industry."

Though apparently successful as a teacher, the headstrong young man was unhappy in his new position. As part of his work in the superintendent's office, he took the "delicate measurements connected with the boring and rifling of 7″ and 8″

guns made at the navy yard for mounting on small gun boats." His work brought him only the "equivalent of three cents an hour in American money though by a little mishap I might at any time have brought on losses of thousands of dollars."[11] Elsewhere it is stated that the pay connected with the position was so low that Barth could not adequately clothe himself, and "for that reason I concluded to emigrate to this country to try to get a job that would enable me to earn a complete livelihood."[12] An experience that contributed to the young man's determination to migrate had to do with chain testing in the navy yard. For private individuals, Barth explains, this work had been done on overtime and the person in charge of the testing received half a crown an hour as pay. It fell to Barth's lot, however, to do the work during regular hours for 10 *øre* (then about 2½ cents) an hour. The superintendent's weak explanation was that "while he felt that I was entitled to the extra pay that had always gone with his private chain testing, and while he would be glad to give it to me personally, he did not dare to do so, because I might get a successor who would not deserve it."[13] To make matters worse, Barth questioned the calibration of the chain-testing machine, which he found to be incorrect, and he refused to sign a test report. He was ridiculed by the director of the shops, a naval officer, for doubting the calibration, which had been made by the navy's great mathematician, Captain Geelmuyden. Barth finally proved the authority wrong and was asked to recalibrate the machine. He derived a formula and worked up a new table which was used by the Norwegian navy for more than half a

[11] Barth made measurements "setting calipers and gauges for the reboring of old cast iron cannons that were to be fitted with new Bessemer rifled steel cores, to make them capable of shooting more modern projectiles." Magnus Bjørndal, "Carl G. Barth," an unpublished biography.

[12] Frank Barkley Copley, *Frederick W. Taylor, Father of Scientific Management,* 2:28 (New York, 1923).

[13] "Carl G. Barth on Scientific Management, Testimony before the Special Committee of the House of Representatives January 31 and February 1, 1912," in Taylor Society, *Bulletin,* 14:206–221, 254–271 (October and December, 1929). Reprint of public document, *Hearings before Special Committee of the House of Representatives to Investigate the Taylor and Other Systems of Shop Management under Authority of H. R. 90,* 3:1538–1583 (Washington, 1912).

century, when the old machine was replaced by a modern one.[14]

"Can you blame me," he asks, "for deciding right then to emigrate to try my luck in America as soon as business should revive over here?" The instructor in drawing also decided to migrate; his position was offered to Barth, "and as a consequence my last year at Horten was spent as . . . instructor in mathematics in the morning and drawing in the afternoon." At the end of the year as instructor, Barth, in spite of being urged to stay, resigned from Horten. In the spring of 1881 he left for America.

The background Barth acquired in Norway was peculiarly important in the light of his future work with Taylor. His passion for metal cutting and his strong aptitude for practical mathematics, as well as his sympathy for labor, were manifested early. His training, though only begun, was thorough and his interests strongly formed. Of even greater importance, perhaps, was his natural ability as a teacher of men and his contempt for rule-of-thumb methods.

Not yet twenty-two years old, Barth obtained work with William Sellers and Company of Philadelphia, one of the greatest machine-tool companies in America and the one from which we obtained our present national standards of threads and tapers. Barth presented himself with his examination drawings from the technical school before Coleman Sellers, Jr., who was so interested that the drawings were taken to William Sellers. He called them the finest ever submitted in support of an application for work. As a result, Barth was offered a job in the drafting room at 2 dollars a day. "This was more than I could imagine myself worth, however, and I humbly suggested that they better start me off at $1.50 only, until they actually found out what I would be able to do for them." His pay was soon raised to 20 dollars a week, "after which I had to make a fight for every additional cent of increase I received."[15]

[14] Bjørndal, "Carl G. Barth."
[15] "Carl G. Barth on Scientific Management," in Taylor Society, *Bulletin*, 14:209

Salary apart, Barth was fortunate to obtain work with the Sellers firm, which in 1881 was at the very height of its career. Barth himself tells us that, in addition to William Sellers, he had "two other exceptional men for . . . superiors." They were Dr. Coleman Sellers (later consulting engineer for the first hydroelectric plant at Niagara), whose inventive turn of mind has been recorded in a statement attributed to him, "Give me time and money and I will do anything"; and his son, Coleman Sellers, Jr. Barth profited from contacts with two other brilliant men who were connected with the firm—John Sellers Bancroft and Wilfred Lewis. Lewis was the first technically educated engineer to be employed by Sellers. To Lewis the young immigrant owed much "for inspiration to improve myself theoretically." Barth was indebted to all these men for guidance in his practical development as draftsman and machine designer.

Barth's arrival in America was well timed. The year 1881 marked "a period of business revival following the long depression consequent on the panic of 1873, with a demand for more and better machine tools."[16] The time "was ripe for furthering the urge for the science of management; while there was already much data on the art of shop management, the methods prescribed by crafts were crude; tools were but poorly fitted to their purpose; time required for completion of a given piece of work was unknown; workmen were frequently unfitted for their jobs; managers could not comprehend delays and vexations arising from unstandardized conditions. . . . Industry was found to be working at about 50% efficiency." Later the inception of high-speed tool steel and its use by Taylor and White "caused Barth to realize the enormous influence this would have on future machine tool construction."[17]

But Barth reached his goal by a circuitous route. After four-

[16] Florence Myrtle Manning, "Carl G. Barth: A Sketch," introduction; an unpublished master's thesis presented at the University of California in 1927. Of greatest value in this document are the corrections and notations made by Barth. It is in a very limited sense an "official" biography. See also her "Carl G. Barth, 1860–1939: A Sketch," in *Norwegian-American Studies and Records,* 13:114–132 (Northfield, 1943).

[17] Manning, Carl G. Barth," introduction.

teen years with Sellers, he left the firm in 1895, having by that time become chief machine designer. His reasons for leaving were several. In the evenings, for six years, he had been teaching mechanical drawing in the Franklin Institute's evening school. For a time he also gave private lessons in mathematics and later, for two years, ran an evening school of his own. As a result of this instructional work and his natural aptitudes, he dreamed of becoming a professor in an American engineering school. "With this in view, I gave up further night work for money, and set to work to utilize all my spare time to further improve my theoretical knowledge of engineering subjects." By leaving Sellers he felt he might "get practical experience in other lines of engineering, so that when I finally presented myself as a candidate for a professorship I might be a strong one." Accordingly, "When the hard times (after 1893) came on, and the company wanted to cut everybody 20 per cent, including a countryman of mine who had worked directly under me for two years . . . I protested that I thought the only fair thing to do would be first to raise everybody that would have received an increase of pay in normal times before the proposed cuts were made." Naturally this proposal was rejected. Barth's opportunity to change came when a former student and friend, Stuart E. Freeman of St. Louis, helped him to obtain work with an engine-building concern in that city. This position, while poorly paid, opened a new field of work into which the young idealist plunged with characteristic energy.[18]

After two years as chief draftsman with the Rankin and Fritch Foundry and Machine Company, Barth was again without a job, his firm having liquidated. "While waiting for something more suitable to turn up," he designed machinery for the water commissioner of St. Louis. But in the same year, 1897, he again went back to teaching, joining the staff of the International Correspondence Schools at Scranton, Pennsylvania. The next year he was instructor in mathematics and manual work at the Ethical Culture Day School in New York City. It was while

[18] Copley, *Frederick W. Taylor,* 2:30.

Barth was employed there, not entirely satisfied with his lot, that his old friend Freeman, who understood Barth better than others, recommended his impetuous young Norwegian friend to Frederick W. Taylor. Taylor at that time was attempting to put metal cutting on a strictly scientific basis at the Bethlehem Steel Company and was unable to reduce to a formula a mass of data at hand. In a quandary, Taylor wrote on March 22, 1899, asking Barth to come out to Bethlehem. The result of this invitation was that in June of the same year Barth became an employee of the Bethlehem company and began a partnership with Taylor that revolutionized shop practices in America.[19]

III

Scientific management in its early phase might be defined as the use of certain scientific formulas to increase the output of both men and machines in the production process. It does not indicate arbitrary attempts to increase production regardless of human endurance. Frederick Taylor, while working as foreman for the Midvale Steel Company prior to his days at Bethlehem, had come to the conclusion that "the greatest obstacle to harmonious cooperation between the workmen and the management lay in the ignorance of the management as to what really constitutes a proper day's work for a workman."[20] With the permission of the president, William Sellers, Taylor set out to find some rule or law that would determine how much heavy work a man well suited to his job should do in a day.

Taylor and his assistants had conducted three sets of experiments. The basic problem, however, of finding a law "as to what constitutes a full day's work for a first-class laborer," was still unsolved, despite the carefully recorded facts resulting from the experiments. The task of formulating the law was later turned over to Barth, along with the mass of data. In Taylor's words, he and Barth decided "to investigate the problem in a new way, by graphically representing each element of the work

[19] Copley, *Frederick W. Taylor,* 2:24, 30.
[20] Taylor, *Principles,* 31.

through plotting curves, which should give us, as it were, a bird's-eye view of every element."

In a comparatively short time Mr. Barth had discovered the law governing the tiring effect of heavy labor on a first-class man. . . . The law which was developed is as follows:

The law is confined to that class of work in which the limit of a man's capacity is reached because he is tired out. It is the law of heavy laboring, corresponding to the work of the cart horse, rather than that of the trotter. Practically all such work consists of a heavy pull or a push on the man's arms, that is, the man's strength is exerted by either lifting or pushing something which he grasps in his hands. And the law is that for each given pull or push on the man's arms it is possible for the workman to be under load for only a definite percentage of the day. For example, when pig-iron is being handled (each pig weighing 92 pounds), a first-class workman can only be under load 43 per cent. of the day. He must be entirely free from load during 57 per cent. of the day. And as the load becomes lighter, the percentage of the day under which the man can remain under load increases. . . . As the weight grows lighter the man can remain under during a larger and larger percentage of the day, until finally a load is reached which he can carry in his hands all day long without being tired out.[21]

When Barth went to Bethlehem in 1899, he went to work on machinery to become acquainted with Taylor's method of tool testing and experimenting. He came to admire Taylor and at the same time to recognize his psychological shortcomings when dealing with men. Taylor was imperious, as he no doubt had to be to overcome the opposition or indifference with which his pioneering work was met by managers and workers alike. But Barth could work with him, though in many respects he was as imperious as Taylor himself.[22]

According to Copley, Taylor's biographer, one of Taylor's chief assistants, H. L. Gantt, "had plotted some experiments made to determine the relations among depth of cut, feed, and speed, while all other variables were held constant." Copley explains:

One day while he still was helping to run the experimental lathe Barth happened to see the plot on Gantt's desk, and was told by

[21] Taylor, *Principles*, 33.
[22] Copley, *Frederick W. Taylor*, 2:27, 31–36.

him that he had tried in vain for about six weeks to construct a mathematical formula to represent its curves. Unhesitatingly and abruptly, Barth declared: "I'll eat my hat if I can't work up an acceptable formula this evening and bring it in in the morning."

He did not have to eat his hat. The fact was, he says, that he at once recognized the curves drawn for the plot as "capable of being more or less closely expressible mathematically by a very simple equation." Now what was Taylor's emotion? To borrow a saying of the Russian peasants, he was as proud as a cock with five hens. He was as proud as if the achievement had been his own. Nothing now was too good for Barth. Immediately he was taken from the lathe, and placed in charge of all the experimental work as well as all the mathematical.[23]

Barth was told "he must study everything that had been done before."

After spending about a week skimming through the accumulated data, he became convinced that an attempt to make himself thoroughly familiar with it would only be a hindrance to him, and over this he and his chief had a battle royal. To all of Taylor's insistence that he should make that study he opposed a sturdy no. What had been done before, said he, was simply a groping in the darkness. He refused to follow other people's darkness. He would seek his own light.[24]

The story of how Barth devised his famous slide rules for use in machine shops is best told by himself.[25] Capable of regarding his work with the same objectiveness he would apply to a mathematical problem, he is an unfailing guide through a labyrinth of technical difficulties in the way of the student.

Before Barth joined the group at Bethlehem, "Taylor and his co-workers of that period had sought to discover some rapid methods of applying the experimentally obtained knowledge of the laws underlying the cutting of steel with carbon steel tools, to the predetermination of the most economical feed and speed for any particular piece of work in connection with any particu-

[23] Copley, *Frederick W. Taylor,* 2:32.

[24] Copley, *Frederick W. Taylor,* 2:33.

[25] It must be remembered that he devised several, not just one. See, for example, "Barth's Gear Slide-Rule," in *American Machinist,* 25:1075 (July 31, 1902); "Barth's Lathe Speed Slide Rules," in *American Machinist,* 25:1684 (November 20, 1902); United States patent number 753,840; and Barth's "The Improved Belt Slide Rule," in *Management Engineering,* 2:351–354 (June, 1922).

lar lathe or boring mill, to which two types of machines they very wisely confined their attention to begin with." [26]

Barth continues:

> The mathematical problem confronting Mr. Taylor and his co-workers, including myself, may be stated as consisting in, how to determine that feed and speed of a machine that will at the same time utilize a maximum of the power the machine is capable of developing at that speed, and the ability of the cutting tool itself to stand up to the work an economical length of time before giving out, on a piece of work of a certain degree of hardness, and of a certain diameter to be reduced to a certain smaller diameter.

A crude slide rule, which did not satisfy Taylor, had already been worked out by H. L. Gantt and S. L. Griswold Knox in an attempt to solve the problem. Barth himself went to work and produced an equally crude instrument accompanied by diagrams. Later he undertook an independent study of both slide rules; this study enabled him to make true logarithmic scales, straight and circular, of any size. Barth explains:

> As a result of this I soon produced an instrument that was a real logarithmic slide rule in circular form, patterned after the Sexton Omnimeter, and which I still have reason to believe was a decidedly better instrument than its "competitor," in spite of assertions to the contrary by my friend Mr. Gantt, who soon facetiously dubbed my rule "Barth's Merry-Go-Round." Be this as it may, it at best furnished only a somewhat quicker, and at times more correct cut-and-try solution; and Mr. Gantt's critical attitude toward it, which, with Mr. Taylor for a while "sitting on the fence," kept both instruments from being put in actual use, finally proved a blessing in disguise by spurring me on to renewed efforts. These soon resulted in the construction of a straight slide rule that gave a direct, and almost instantaneous solution of the problem, and which together with the necesary accessory, interchangeable slides for 13 lathes using roughing tools identical with Taylor's standard experimental tool, was ready to be put into practical use on December 1, 1899, just five months and a half after my arrival and first introduction to the whole subject.

In Barth's eyes his "slide rule represents something more than an 'improvement' on the instrument that had previously

[26] This account is based on Barth's famous "Supplement to Frederick W. Taylor's 'On the Art of Cutting Metals,'" in *Industrial Management,* 58:169–175, 282–288, 369–374, 483–487 (September–December, 1919).

been used. It represents a distinct departure from previous practice." On it were incorporated "the first empirical formulas that in a simple and straightforward manner expressed the law of relations between depth of cut, feed and cutting speed, as constructed by me from the first set of experiments made with high-speed tools to arrive at this law." The solution effected by means of Barth's compound slide rule "is neither more nor less than the solution of two simultaneous equations each containing two unknown quantities; viz: the feed and the speed."

An estimate of the complexity of Barth's problem is obtained when it is stated that no less than twelve variables were involved in determining the most economical way in which to do a certain bit of work on a machine. They were, to use Barth's own enumeration:

I. The size and shape of the tools to be used.
II. The use or not of a cooling agent on the tool.
III. The number of tools to be used at the same time.
IV. The length of time the tools are required to stand up to the work (Life of Tool).
V. The hardness of the material to be turned (Class Number).
VI. The diameter of this material or work.
VII. The depth of the cut to be taken.
VIII. The feed to be used.
IX. The cutting speed.
X. The cutting pressure on the tool.
XI. The speed combination to be used to give at the same time the proper cutting speed and the pressure required to take the cut.
XII. The stiffness of the work.[27]

All of these variables except the last were incorporated on the rule.

In recounting Barth's efforts to work out his slide rule, Taylor writes:

If a good mathematician who had these various formulae before him were to attempt to get the proper answer (*i.e.*, to get the correct cutting speed and feed by working the ordinary way) it would take him from two to six hours, say, to solve a single problem; far

[27] Carl G. Barth, "Slide Rules for the Machine Shop as a Part of the Taylor System of Management," in American Society of Mechanical Engineers, *Transactions,* 25:50 (1904).

longer to solve the mathematical problem than would be taken in most cases by the workman in doing the whole job in his machine. Thus a task of considerable magnitude which faced us was that of finding a quick solution of this problem, and as we made progress in its solution, the whole problem was from time to time presented by the writer to one after another of the noted mathematicians in this country. They were offered any reasonable fee for a rapid, practical method to be used in its solution. Some of the men merely glanced at it; others, for the sake of being courteous, kept it before them for some two or three weeks. They all gave us practically the same answer: that in many cases it was possible to solve mathematical problems which contained four variables, and in some cases problems with five or six variables, but that it was manifestly impossible to solve a problem containing twelve variables in any other way than by the slow process of "trial and error." [28]

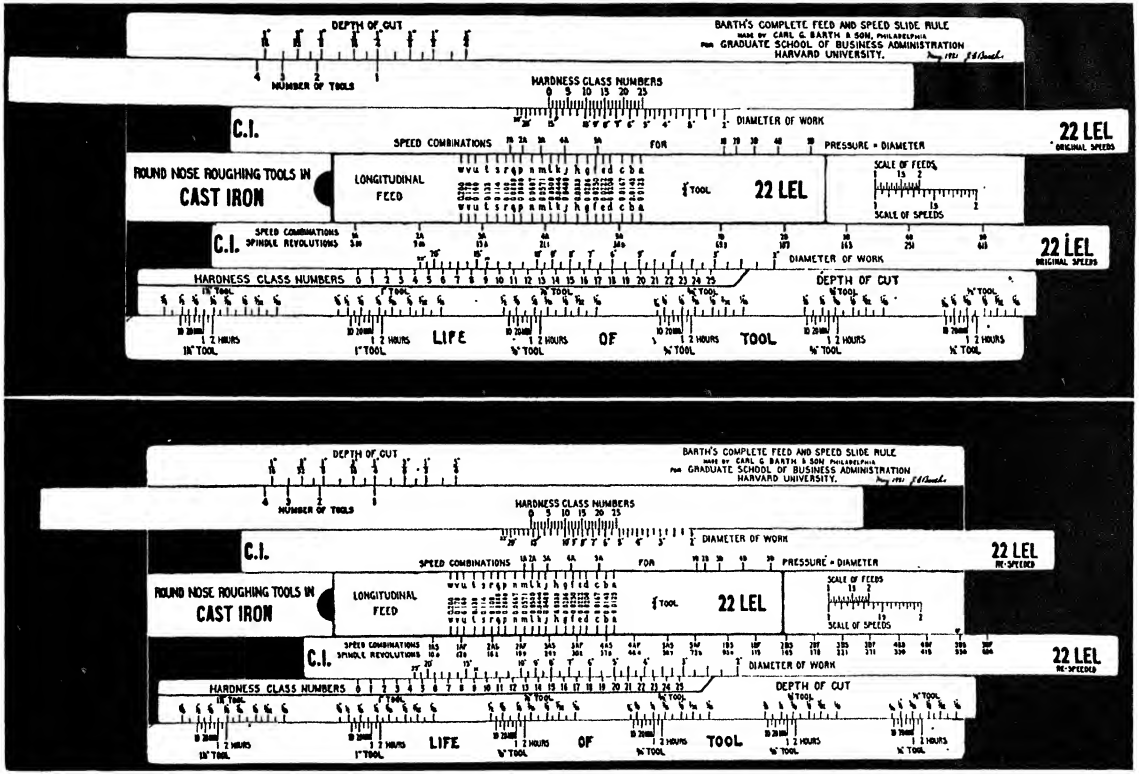
Barth, in solving the "impossible," made it quite possible for any good mechanic to work out intricate mathematical problems in less than half a minute and to hit upon the one best combination of speed and feed out of the many possible combinations before him. He thus eliminated rule of thumb from the operation of cutting metals. "A magic instrument, that slide rule," concludes one writer. "An abolisher of guess work, opinions, arguments, debates. A determiner of the law! . . . The best we can hope for, in the case of any law, is that the expression be as exact as need be in the light of practical requirements, and it is such an expression as this that is insured by that slide rule." [29]

IV

As late as 1919 one of the editors of *Industrial Management* stated that while high-speed tool steel had increased machine-shop production some two to four times, few shops knew how to increase it still further by the best combination of machines, tools, feeds, and speeds. "In fact," he wrote, "the only practical way in which such a solution can be found is by the use of the Barth slide rules." [30]

One would be inclined to assume, in the light of the great

[28] Taylor, *Principles*, 57. Taylor's statement embraces more than the slide-rule operation, which applies only to the machine portion of a job.
[29] Copley, *Frederick W. Taylor*, 2:35.
[30] L. P. Alford, in vol. 58, p. 171 (September, 1919).



A Barth Slide Rule

American Society of Civil Engineers.

The proposal for MEMBER, ASSOCIATE, or JUNIOR, shall contain a statement, over the *candidate's signature*, of his *age, residence*, the nature and term of his *professional service*, and that he will conform to the requirements of membership if elected.

STATEMENT.

I Peter C. Asserson
(Full Christian names and surname of candidate)

residing at U.S. Navy Yard Norfolk Va
(City or town, county, State)

being desirous of admission into the American Society of Civil Engineers as a Member (State class of membership) submit the following as my professional record:

I was born at Norway Europe (Place of birth)

on 5th day of January 1839. (Date of birth) To embody

for all classes of members, except Fellows, a concise narrative, with dates, of the candidate's professional career, specifying the positions he has held, the nature and extent of the works in or upon which he has been engaged, giving an idea of their magnitude and importance. All proper names, names of railroads, etc., must be written without abbreviation.

From the age of 7 to 12 received a Common school Education from 12 to 16 years of age studied Civil Engineering Astronomy and Navigation. from 16½ to 18 years of age was employed as 2nd asst. Engr. erecting a stone Tower Light House on an isolated rocky promontory on the Isle of Egersund Norway, on the completion of this work went to Sea as Sailor 2d and 1st Officer of different Vessels, Eur & American in 1859, assisted in erecting a large screwpile Light House in the Gulf of Mexico also assisted in the Hydrographic Survey of the Gulf of Mexico, entered the Naval Service in 1862 as a line officer, had command of several Gunboats during the war, in 1869 received an honorable discharge from the Navy from that time until 1874 was engaged in the important work of clearing out obstructions in the Elizabeth, James, and Rappahannock Rivers &c. successfully raised 4 Line of Battle Ships, & removed the remains of the famous "Merrimac", Florida, two large Iron Clads and a large number of smaller vessels and Crib work by submarine blasting, Entered the Naval service again as a Civil Engr. in 1874 since that time have been the resident Civil Engineer in charge of all Public works Navy Yard Norfolk. besides the building of several Magazines Shell Houses R.R. and Concrete Quaywall at Craney Isl. 6 miles from Norfolk I am now the Senior Civil Engineer on the active list in the Navy

I will conform to the requirements of membership.

FOR MEMBER ASSOCIATE OR JUNIOR	if elected as Member (state class of membership)

"The applicant will sign here his regular signature,

P. C. Asserson

and give his present post-office address

Civil Engr. U.S.N.

Navy Yard Norfolk Va

Rear Admiral Asserson Applies for Membership in American Society of Civil Engineers

need here expressed, that the slide rules, once manufactured and tested, could be marketed like any other commodity and thus be made available to machine shops everywhere. Such, however, is not the case. Speaking specifically of a slide rule for belts, Barth explains that "the principal reason why the writer has never cared to put this rule on sale in the open market is that considerable misuse has been made of it, even by persons from whom one would expect better judgment." He then illustrates his point by referring to misuse of the rule at one of the United States arsenals.[31]

Elaborating on this theme, J. Christian Barth, who was once in consulting practice with his father, explained to the writer that the rules were handmade; three movable sticks were specially prepared for a particular machine or a group of identical machines after an engineering study had been made of the driving mechanisms revealing weaknesses, irregularity of speeds and feeds, lack of power, and the like. The machines were then redesigned and rebuilt to new requirements and the information indicated on the three movable sticks. The Barths required, before installing their rules, that a certain amount of the routine and principles of the Taylor system be introduced and in fair working order in the plant. Thus it was expected that the purchase and storing of materials, the whole control of production, and the system of cost recording be in harmony with Taylor's general practice. The study of the machines with a view to respeeding them, the introduction of the slide rules, and the use of time study and incentive wages were the last, not the first, consideration. Without the first steps, the rules could become instruments of great misuse in the hands of unscrupulous management.[32] Commercialization would be conceivable only if all tools and machines were standardized, as Barth argued they should be. In the hands of an unskilled manager, under existing

[31] Barth, in *Management Engineering,* 2: 351–354 (June, 1922).

[32] A short time before Barth died he was convinced that his rules were obsolete—that is, the mathematics incorporated thereon. Improved materials and tool steels required, he thought, new experiments, a reworking of formulas, etc. During his working years slide rules were made on an average of once every five years — and only for clients.

conditions, the rules would work havoc with machines and an injustice to the men. One cannot, parenthetically, help wondering if another inventor would have been as scrupulous as Barth proved throughout to be.

In capable hands, however, the slide rule worked wonders when used as an integral part of the Taylor system of management. In 1903 Barth set himself up in consulting practice, and was later joined by his son. He soon counted among his clients some of the country's leading private producers and the arsenals of the United States government. Rules were made for machines in the plants of such firms as Yale and Towne, Link-Belt, Pullman, and others. The story of how Barth went into this work, how the Taylor system functioned in practice, and his procedure when once engaged is recounted in his testimony before a special investigating committee of the House of Representatives.[33] He explains:

> I had no intention on leaving the Bethlehem Steel Co., when Mr. Schwab took the company over, to go into the system at all; but Mr. Taylor thought that I had shown special qualifications for undertaking the work, and so he got in touch with William Sellers & Co. and persuaded them to engage me to conduct further experiments in the line of the development of the art of cutting metals, with a view of introducing our slide-rule method of running their machines. Additional experiments were needed because our investigations had up to that time covered only larger tools.

No experiments in cast iron had yet been made.

After fifteen months of hard work, the experiments at William Sellers and Company were completed, but for reasons of internal policies the results of the project were never put into effect for that firm. Taylor then found employment for Barth with the famous Link-Belt Engineering Company, "to introduce the mechanical part of the Taylor system, and there to make use of the information for which Wm. Sellers & Co. had paid. . . . Other men were at the same time selected to take up the general administrative end of the system." Before the job was completed, however, it became necessary for Barth to look

[33] Taylor Society, *Bulletin,* 14:206–221, 254–271 (October and December, 1929).

after the entire undertaking, "so that after a while the whole burden of standing between Mr. Taylor, who did not visit us any too often, and the company itself, in the introduction of the system fell on me, and during the following two years I might have been considered as having served the last part of my apprenticeship under Mr. Taylor."

The Link-Belt Company had long been regarded as having "an exceptionally well-run shop, and they particularly prided themselves on being able to bore holes better than anybody else in the world." Barth soon found, however, that the shop was poorly run. "For two years they had had high-speed steel in the works, but they neither knew how to treat nor grind it so as to get any benefit from it. . . . The first work I did was scientifically to investigate their machinery, and speed it according to our methods." The machinery in good shape, he next "put two lathe hands to work on the full Taylor system, so far as the shop is concerned. We selected a gang boss, a speed boss, and an inspector, and started in to make an object lesson, in connection with these two lathes, of what we meant by functional foremanship." The gang boss was made responsible "for seeing that there always was work ahead for these lathes, that the proper tools were also secured, and he also looked after the men's time." The speed boss saw to it "that the men ran their machines according to instructions issued from the embryo of a planning department, consisting of myself as the slide rule man and maker of instruction cards." The inspector "saw that the work produced under the supervision of the speed boss was acceptable. At first there was no time study, but the men received 35 per cent additional day wages for thus working under instructions and direct supervision." From this humble beginning, Barth relates, "we added man after man, and in the meantime appointed a man from the shop to take up the slide rules under my directions, and little by little we added time study and task work with bonus, for which, later on, Mr. Taylor's differential piece work was substituted." On this job, as on all others

later on, Barth had no trouble with the men working under his supervision.[34]

An indication of how effectively Barth could increase machine output is given by other experiences. While introducing the Taylor system at Yale and Towne Manufacturing Company, he found a man milling a key seat in a shaft. "From the particular manner in which the chips came off, my experience told me that it was a very soft shaft, and that, without knowing anything about the work in any other way, it would be possible to make a great increase in the rate of cutting that key seat." He discovered that the man was using a cutter with one broken tooth. While waiting for a new cutter to come from the toolroom, Barth got out his slide rule for milling work and "by means of this determined a suitable feed and speed for the cutter . . . and then picked out the nearest of these that his machine had. I also sent for the foreman and other witnesses to see what I was doing to instruct the man." The result was that, while the teeth of the new cutter were longer than those of the old cutter and more apt to break in case of overwork, "in a mere fraction of the time previously taken I cut the key seat the full length, to the great astonishment of everybody concerned."[35]

In the same shop, while establishing a planning department and improving the shop equipment, Barth showed a first-class machinist "how he could run his tool on a lathe 80 times faster than I found him running it." A concern that had been using high-speed steel for over two years with no appreciable benefit from the innovation wrote to Barth asking him to demonstrate in their establishment the proper method of handling high-speed steel.

This I agreed to do, stating that the best way of doing it would be by means of a slide rule for one of their best lathes, for which I then requested that they make me a diagram showing all its speed and feed mechanism, and countershaft with pulleys and line-shaft speed. On receipt of this, I found the lathe entirely under-speeded. . . . The performance that followed was witnessed by

[34] Taylor Society, *Bulletin,* 14:211–213.
[35] Taylor Society, *Bulletin,* 14:214.

some twenty foremen, who then and there were made to realize that their rule-of-thumb methods counted for nothing as against the science of my "guessing sticks"; for they were made to understand that I had never seen the lathe itself before then, and had become acquainted with its properties only by a study of the diagram sent me. The result was that I was immediately retained by the company.[36]

Frederick Taylor tells of a case where Barth went to introduce scientific management into the works of a man who, "at between 65 and 70 years of age, had built up his business from nothing to almost five thousand men."[37] Apparently this owner was a person with a disposition not unlike Barth's, for Taylor tells us that they "had a squabble, and after they got through, Mr. Barth made the proposition, 'I will take any machine that you use in your shop, and I will show you that I can double the output of that machine.' A very fair machine was selected. It was a lathe on which the workman had been working about twelve years." The product of the shop was a patented machine of many parts; there were 350 men making these parts the year around. Barth set out to prove his boast; with one of his slide rules, he "proceeded to analyze the machine. With the aid of this analysis . . . Mr. Barth was able to take his turn at the machine; his gain was from two and one-half times to three times the amount of work turned out by the other man. . . . That is not exaggeration, the gain is as great as that in many cases."

These and many other instances prove beyond any doubt the efficacy of Barth's slide rules as a part of the Taylor system and at the same time demonstrate clearly the truth of Taylor's contention that "the art of cutting metals involves a true science of no small magnitude, a science, in fact, so intricate that it is impossible for any machinist who is suited to running a lathe year in and year out either to understand it or to work according to its laws without the help of men who have made this their specialty."[38]

[36] Taylor Society, *Bulletin*, 14:215–218.
[37] Taylor Society, *Bulletin*, 2:21 (December, 1916).
[38] Taylor, *Principles*, 53.

V

It was inevitable that scientific management, with its separation of brain and shop work and its preoccupation with the individual worker, would in time clash with the trade unions, which stressed the group solidarity of workers and jealously sought to guard the craft secrets of its members. One authority writes:

> It is easy to see why unions could not put up much of a fight in shops operating under such a system. In so far as it centralizes skill, scientific management takes from the workmen that bond of common craft knowledge, which tends to make brothers of the men engaged in a trade. Since it pays on an individual or efficiency basis, and promotes the more able men to fill positions as functional foremen, scientific management appeals to personal ambition, rather than to class solidarity. . . . As it voluntarily pays higher wages than the men could win through force, scientific management weakens the main motive for organization.[39]

The surprising feature of labor's relation to the work of Taylor, Barth, and others is therefore not its opposition but the absence of trouble in plants where scientific management was actually introduced. Such trouble as did arise came largely as the result of the efforts of so-called "efficiency engineers" and other quacks, the "speed-up" of production, which drained the energies of workers, and a general failure of management to follow Taylor's major principles. When conflict came it was largely in the field of doctrine and it developed in some measure as a by-product of misunderstanding; but labor rightly sensed that researches in production would make the knowledge of craft skills the common property of management.[40]

Seeing the futility of fighting scientific management in the shop, organized labor turned to Congress for help. In the fall of 1910 the Interstate Commerce Commission conducted some rate case hearings that were destined to have a profound effect on labor's attitude. These hearings were held in response to a

[39] Horace B. Drury, "Scientific Management and Progress," in Taylor Society, *Bulletin*, 2:5 (November, 1916). A more detailed and critical account of this subject is R. F. Hoxie, *Scientific Management and Labor* (New York, 1915).

[40] Person, in *Encyclopaedia of the Social Sciences*, 13:607.

demand by certain railroads that they be permitted to increase their rates in order to offset a general rise in wages. The shipping interests of the Northeast argued that, instead of raising rates, the railroads should reduce their costs, and offered evidence that costs could be cut and savings effected by the Taylor system, which had already been introduced into certain industrial plants. Out of these hearings grew the expression "scientific management."[41] Out of them, too, came the organized opposition of the American Federation of Labor to the movement, which the unions hoped could be killed by political weapons. Congress was particularly interested in labor's opposition because scientific management was then being introduced into the federal arsenals and was soon to be proposed for other departments of the government as well.[42] In addition, Congress felt it could not wisely ignore the growing strength of labor at the polls in the dynamic years immediately preceding the outbreak of World War I. Labor, which ironically was helpless to prevent the growth of scientific management in the industrial field, came to exert a great influence in national political affairs.

At a later date Barth went on record with the statement that "with one single and deplorable exception," no direct disciple of Taylor ever timed a worker without "properly preparing the way and obtaining the full consent and cooperation of the worker."[43] The exception occurred at the government's arsenal at Watertown, Massachusetts. During the absence of Barth, who had charge of introducing the Taylor system at Watertown from 1908 to 1912, labor trouble broke out when an unqualified man, under pressure from army officers, went into the foundry to start time-study work on molders without first preparing the workers psychologically.[44] The results were an illegal strike of foundry workers, a temporary shutdown of the arsenal, and, as might be expected, increased interest in scientific management. Labor leaders succeeded in bringing about hearings before a

[41] Person, in *Encyclopaedia of the Social Sciences,* 13: 603.
[42] Drury, in Taylor Society, *Bulletin,* 2: 6 (November, 1916).
[43] "A Defense of the Stop Watch," in Taylor Society, *Bulletin,* 6: 111 (June, 1921).
[44] Information given by J. Christian Barth of Philadelphia.

special committee of the House of Representatives to investigate the Taylor and other systems of scientific management. Barth's testimony before this body, January 31–February 1, 1912, an illuminating commentary by an insider, reveals better than any other document the almost crusading idealism which motivated men like Barth and Taylor. Whatever the subsequent abuses by employers and pseudo-efficiency men, in the hands of Barth scientific management was a means toward the betterment of the working classes, of which Barth always considered himself a member.

Quoting from a report on his work at the Watertown Arsenal, Barth explained:

> The main object of the Taylor System, as I am working for it — I do not care what the other fellow is working for — is to eliminate waste of time, materials, and human energy, and so to utilize the machinery of a plant that a greatly increased production will result in lower cost of production to the owners and, on the other hand, in increased wages to the employees. . . . I am personally only directly interested in the latter part of this — namely the increased wages of the employees — and in the former merely because, without bringing this about, the latter can not be brought about.

He thus agreed with the modern economist.

Always passionately honest, Barth hastened to add, "I will not deny that I am also intensely interested in the introduction of this system, merely as an outlet for my natural energy and love of work for its own sake."

In his testimony Barth recounts case after case to prove that the workmen caused no trouble of their own volition in the shops where scientific management was introduced. To the contrary, the inherent individualism of American workers asserted itself quickly. Speaking of his work at the Link-Belt Company, Barth said, "It was not very long before men commenced to bother us because we were not able to get around fast enough to put them in a position to make the extra money." Workers generally increased their earnings under Barth by 30 per cent or more.

Answering the charge that scientific management, while it

might eliminate loafing or "soldiering" on the job, made "automatons of the men," Barth declared with sincerity and a bit of naïveté:

> The fact about that is that, in my experience and judgment, we produce far fewer, for the reason that the management itself keeps so closely in touch with what is going on that they more readily see the inhumanity of making automatons of human beings. I do not recollect that in all the 13 years that I have been connected with Mr. Taylor's work that I have come across a single case as bad as one I found in the shop I told about: namely, that of an old man driving little bits of rivets in certain parts of platform scales, which had been his only work for 42 years past. I do not believe that this would have existed under scientific management.

Asked about the case, Barth explained that it was at Fairbanks, Morse, and Company, and that under scientific management a machine would have been invented to do the worker's job and the man trained to handle the machine "instead of using his own hands and arms to work that hammer up and down." Asked what would happen if he had been unable to invent the matons of the men," Barth answered:

> We would probably have distributed that work, at least I should judge we would have had men taking turns at it, along the principles laid down long ago by Mr. Bellamy in his wonderful book "Looking Backward," in which he suggests that the time will come when all disagreeable labor in this world will be divided equally between all able-bodied men, so that a certain number of days out of every man's natural life will be spent in performing that service to the world.

While Barth's difficulties with personnel, such as he had, came from foremen and managers, he was unwilling to say that the conduct of business should be taken from management. He explained:

> The way business is conducted today there can be no other way than that management lays down the general policy. For instance, I do not think that anybody today could find exception with the management for either wanting to introduce a system like ours or for not wanting to. . . . It would be impossible at the present state, when the system is so absolutely misunderstood, not only by most workmen but even by most managers, to get an expression of opinion that would be worth anything whatsoever; and for this

reason the general policy of management must still be vested in the management.

Asked if he did not think it wrong that management should have absolute power in dealing individually with workers, Barth answered:

On that score I used to feel and think a great deal, as a younger man. I keenly felt, and still feel, the injustice of the present order of society. I have suffered much because I have expressed opinions against it to people who are satisfied with things as they are. I have arrived at the conclusion, however, that whatever general conditions exist at any one period of the world's history is, in the main, part of a natural development which can not easily be changed into anything better except through further slow and painful development of each individual rather than of the development of society as a whole.

I have learned to look upon myself as one of the little bricks in the building up of the future grand humanity, and I want to try to be as good a brick as I can with my limited abilities and opportunities; and in my present work I believe that I have found a little niche in the world that I can fill, not only without detriment to anybody, but even with some beneficial influence on my immediate surroundings. I am a product of these surroundings; and I have to work in these surroundings as I find them; and I do not see how I can work as an engineer without accepting the proposition, the ordinarily accepted theory, that the manager or the owner of a business has a right to lay out the general policies; because, as a rule, he is a broader man than the men who work for him, and because as an individual he has more at stake, as things are now constituted.

I am very much concerned that the statesman, as his enormous task in the world, shall eventually find a solution for the present wrong order of society, and as one part of that solution the proper distribution of all wealth produced. But I do not consider that it is given me to become a statesman and meddle with these affairs, so I have resigned myself to my fate of doing my share of the world's work as an engineer, whose business it is to do all he can to produce wealth without in any way oppressing any individual or class of individuals, but, on the other hand, to do it along so broadminded lines that he helps men to develop, so far as possible, into the highest type of normal human beings.

While Barth and others like him understood the plight of the American worker, there was an unmistakable tendency among some employers so to utilize scientific management as "to speed

up production but to ignore the incentive wage."[45] Barth may have failed fully to grasp the significance of turning all production problems over to engineers—and thus of encouraging ruthless employers—but no one acquainted with his career can question his concern that the effects of scientific management should add up to positive benefits for the individual worker. And time alone will fully determine whether or not Barth was right in assuming that the laborer's position, in the long run, would be bettered only when his output was increased—with the aid of scientific management. Parenthetically, it may be remarked that Barth considered labor unions essential to guarantee a just portion of the national income to workers; but he deplored the rapacity and shortsightedness that made them a necessity in modern society.

VI

Until his death in 1915, Taylor was undisputed leader in exploiting the new science of production. After 1915 Barth took his place as the leading exponent of the system that he helped develop during a long and intimate association with the "father of scientific management." Spurning attractive offers for the cheap commercialization of his system and the slide rule, Barth, unlike many, remained faithful to Taylor's basic principles. His contributions after 1915 might be grouped together as a general refinement of the program already laid out. According to Miss Manning, "It was the thorny path of the pioneer that Barth had to follow. . . . Barth gave himself without stint in long, tedious hours of experimental work, sacrificing . . . refining, revising and reducing the work wherever possible to mathematical formulae."[46]

Barth was particularly interested in the standardization of machine tools. In 1916 he pleaded brilliantly before the American Society of Mechanical Engineers to induce members "to adopt certain standards for machine tools" which he considered

[45] Lois Macdonald, *Labor Problems and the American Scene*, 583 (New York, 1938).
[46] Manning, "Carl G. Barth," 3.

essential to the installation of the Taylor system.[47] Two years earlier he had argued forcefully before the Commission on Industrial Relations for a "common standard of speeds and feeds so that, for instance, the drilling of a one-inch hole in a certain grade of material might be done with the same speed and feed in accordance with a standard practice, and hence, in exactly the same time the world over."[48] One can only imagine the effect on production, had Barth's policy been put into effect, as one day it may be.

Barth was a pioneer, too, in the field of wage incentives to stimulate worker output and abolish "soldiering" on the job. His method, the Barth premium system, called for close cooperation with the worker and automatically took care "of different rates of hourly pay based on the capacity of different men to produce varying amounts of work."[49] He was perhaps the greatest authority in his day on the subject of the transmission of power by leather belting.[50] He was a strong advocate of the central planning room "that deals with each manufacturing department as does a local planning room in each of the several manufacturing departments deal with its individual machines and other work places."[51] Of inventive mind, Barth had a number of American patents to his credit, individually or in cooperation with others.[52] Eager to apply the mathematical method to social and economic questions, he contributed inter-

[47] "Standardization of Machine Tools," in *Transactions*, 38:895–916 (1916).

[48] Quoted in Manning, "Carl G. Barth," 36.

[49] *American Machinist*, vol. 32, part 1, p. 464 (March 25, 1909). See also synopsis of the proceedings of the twelfth annual convention of the National Metal Trades Association, April 13 and 14, 1910, reprinted in *Industrial Engineering and the Engineering Digest*, 8:214 (September, 1910); *Iron Age*, 85:1068–1070 (May 5, 1910); *Management and Administration*, 8:71–73 (July, 1924).

[50] Carl G. Barth, "The Transmission of Power by Leather Belting," in *Power Transmission*, 29–103 (American Society of Mechanical Engineers, *Papers*, no. 1230—n.d.). The paper was presented at the New York meeting in January, 1909.

[51] Taylor Society, *Bulletin*, 4:23–25 (April, 1919).

[52] Flanging machine (September 8, 1891), with Walter L. Clark; feed-operating device (October 8, 1895); testing machine (January 7, 1896), with William Sellers and John S. Bancroft; slide rule (March 8, 1904), with Henry L. Gantt and Frederick W. Taylor; lathe (May 15, 1917); method and means for measuring belts under tension (December 25, 1917), with Frederick Øyen; method and means for re-forming wheels having worn threads and flanges (October 7, 1924).

esting and original studies on the subjects of labor turnover and the income tax.[53] Fortunately he has left written records of most phases of his work.[54]

Frequent references are found in Barth's writings to a desire to teach others, whether fellow workers or younger students; and mention has been made of his experiences as a teacher at Horten's Technical School, the International Correspondence Schools, and the Ethical Culture School. In 1911 Barth went to Harvard as a special lecturer on scientific management, and continued his association with this school until 1923. He lectured in a similar capacity at the University of Chicago during the years 1914–16. The fact that his associations with the great universities of this country were restricted to a relatively few lectures did not indicate a lack of effort on the part of the schools to enlist his full-time services. During his connection with Taylor at Bethlehem, Pennsylvania State College offered Barth a professorship in machine design, as did Lehigh University. Earlier he had been offered a chair at Cornell. The handsomest offer, however, came during his work with Taylor. When Harvard was planning its graduate school of business and finance, Professor Edwin Gay was empowered to find a man qualified by experience and scientific training to take charge of the school. Gay turned first to Taylor who, in refusing the post, pointed to Barth as the only other person qualified for the position, but added, "You can't have him, he does far more useful work in the industrial world than he could do at Harvard." Gay twice offered the position to Barth, although he was past the usual age limit of forty-five and had no academic degree. Recog-

[53] "Labor Turnover, a Mathematical Discussion," in Taylor Society, *Bulletin,* 5:52–58 (April, 1920); "The Income Tax, an Engineer's Analysis with Suggestions," revised reprint from Engineers' Club of Philadelphia, *Journal,* 35:280–297, 342–345 (June and July, 1918).

[54] Some of Barth's articles not cited above are "The Distribution of Pressure in Bearings," in Engineers' Club of Philadelphia, *Proceedings,* 10:1–15 (January, 1893); "Betterment of Machine-Tool Operation by Scientific Metal Cutting," in *Engineering Magazine,* 42:586–592 (January, 1912); "A New Graphical Solution for Time Allowances in Task Setting," in *Management and Administration,* 9:143 (February, 1925); "Approximating an Ellipse by Circular Arcs," in *American Machinist,* 67:963–965 (December 22, 1927); and "The Making of Special Slide Rules," in *Mechanical Engineering,* 48:593 (June, 1926).

nizing his lack of educational background, Barth declined the invitation but agreed to lecture on scientific management.[55]

In 1923 Barth retired from active work. Much of his time thereafter until his death in 1939 was devoted to his two hobbies — music and pure mathematics. Fond of music but no performer, he was, as might be expected of one with his experience, vitally interested in the intricacies of rhythm. His major efforts, however, were made in the mathematical field. Continuing a project begun thirty years before his death, he worked out an independent interpretation of the fundamentals of differential and integral calculus. Though it was his ambition to see his simplified study published as an improvement over the conventional Newtonian approach, in this he was disappointed.

A widespread recognition of his contribution to the American economic revolution, however, was given long before his death. Of the many tributes paid Barth by contemporaries, none better sums up his work than a statement made by the Taylor Society upon conferring an honorary membership, "Because of his application of pure science to the uses of management, do we thus honor ourselves and him."

VII

Other Norwegian engineers contributed, though in smaller measure, to the growth of scientific management. Christian Paulsen Berg, after graduating from Horten in 1901, was employed by the Link-Belt Company of Philadelphia and while there devoted his energies to time-study and shop methods. After 1907 he worked for the same firm in Chicago until five years later, when he began professional consulting practice in industrial management as a member of Drake and Berg, Incorporated. In 1910 Berg was awarded the Chanute medal of the Western Society of Engineers for a paper on the "Heat Treatment of High-Speed Tools." In 1932 he returned to the Link-Belt Company and there devoted his remaining years to

[55] Magnus Bjørndal, "Carl G. Barth." Similar information is given by the same writer in *Nordisk tidende*, November 30, 1939.

systematizing shop and office routine. At the time of his death in 1936 a news release by his employers spoke of him as "a man who contributed a lifetime to reduce lost motion, systematize shop practice, and establish scientific management, with the aid of time-study and motion-analysis surveys." [56]

Two men who worked intimately with Barth were Gulow A. Gulowsen and Johan Martin Fredrik Øyen. Gulowsen, a graduate of Horten's Technical School in 1878, began his work in scientific management in 1888, when he joined Taylor at the Midvale Steel Company in Philadelphia. Employed first as a designer and later as chief draftsman, he came under Barth's direction at Bethlehem. One day he displayed drawings of a belt bench which he had designed at home; Barth and Taylor at once recognized its value, since keeping proper tension on belts was an important feature of their equipment technique. This job had formerly been done by a belt fixer who carried a heavy tension scales clamp to each machine whose belts needed tightening, attached the clamp to the belt in its working position, and turned a crank until the required tension showed on the scales. Gulowsen's proposal was to bring the belt to a bench on which the clamps were permanently attached. His bench had two pulleys, one fixed and the other movable; the belt was stretched around the pulleys, its ends pinched in the clamps, and a crank was turned until the scales registered the required tension, when the belt was cut to length and the job was completed. Later, Øyen, working with Barth, adapted regular weighing scales to the bench and was granted a patent on the device.[57] Gulowsen was considered one of the ablest designers of his day. He developed an eight-spindle drilling, milling, and undercutting machine for the automatic cutting of square and oval holes in headers for boilers made at the Babcock and Wilcox Company at Bayonne, New Jersey. He was also the inventor of intricate automatic machinery for the production of fine dental tools at

[56] American Society of Mechanical Engineers, *Transactions,* vol. 60, record and index, p. 48 (1938).

[57] Number 1,250,943 (December 25, 1917); information supplied by J. Christian Barth.

the S. S. White Dental Manufacturing Company in Princes Bay, New York.[58]

J. M. F. Øyen, as Bjørndal has suggested, "belongs to two generations, to two great periods of immigration." A graduate of Christiania's Technical College, he left for America immediately following the completion of his training in 1898. Joining Taylor and Barth at the Bethlehem Steel Company, he became one of the eager group of disciples who made scientific management possible. His association with Barth continued at Yale and Towne, 1905–08, at Smith and Furbush in the next year, and again at the Pullman Company, Chicago, in 1913–14. Øyen is quoted as saying that he thought of his work under Barth until 1909 "as the serving of an apprenticeship. Barth was both a model and despair to any young engineer. He was the fastest draftsman in existence and his work was simply perfect both in appearance and engineering design." Before Barth went to Bethlehem, Øyen was asked by Taylor to assemble data on the machine tools then in use, which facilitated the preparation of slide rules; he was also employed in standardizing the work on machine-tool drives. Before returning to Norway in 1914, Øyen did significant designing of a drilling machine at Babcock and Wilcox Company; in the Old World he sought to introduce, without too great success, the methods he had learned in America. Coming to this country a second time in 1923, he has had varied experiences, including employment with Henry Kaiser in California during World War II.[59]

E. K. Wennerlund's name is identified with the introduction of scientific management into the automobile industry in America. He was born in 1875 in Porsgrund, Norway, but received his technical training at the University of Minnesota, graduating in 1899. He therefore belongs in a slightly different category from the other men discussed in this volume. While working for the Atchison and Sante Fe Railroad at Newton, Kansas, during the early years of this century, he became interested in scientific

[58] Information provided by Øyen through the courtesy of Magnus Bjørndal.

[59] Information from an unpublished biography of Øyen prepared and put at the writer's disposal by Magnus Bjørndal.

management and from 1907 to 1910 had charge of the wage and shop systems of the American Locomotive Company. After a brief experience as assistant vice-president with Allis Chalmers Company in Milwaukee, Wennerlund joined the General Motors Corporation in 1911 and remained with them until his retirement in 1932.[60]

Wennerlund had known Taylor when the latter was introducing scientific management, and he became one of his strong admirers. "All that the rest of us have done," Wennerlund once said, "is simply to take his basic ideas, refine them, and adapt them to big-scale, modern production." The young engineer rightly understood that what Taylor was attempting to do was "to get maximum production from equipment."[61] An apt pupil of Taylor's methods, Wennerlund was asked by W. C. Durant to smooth out production for General Motors. An idea of what he found when he took charge of the shop system for all General Motors plants may be had from a letter written many years later. It reads in part:

> I knew nothing about cars, had never driven one. But these were hard times in the automotive game, only the rich could afford them, some plants were closed, there had been over production. My job was then to line up the plants on a unified manufacturing basis. But the crisis was overcome. Ten years later G. M. built the largest office building in the world, profits became large and with better roads cars were more in demand. G. M. prospered and soon became one of the world's industrial giants.[62]

Elsewhere he is quoted as saying:

> In those days there was little thought to the proper location of automobile plants with respect to other plants and railroads. . . . I was sent to Buick once when they were demanding a new plant. Rearrangement of the floor space there already had enabled us to close four existing plants. . . . Taylor believed, as I do, that a man should be rewarded for producing more than a quota. Our system was to figure the proper output, and then subtract one-tenth, to allow for stoppages, breakages, and the like.[63]

[60] Much of this information was obtained in conversation with Wennerlund at Detroit during 1940–41.

[61] Quoted by Russell Barnes, in *Detroit News,* November 14, 1937.

[62] *Willmar* (Minnesota) *Daily Tribune,* January 22, 1940.

[63] *Detroit News,* November 14, 1937.

Wennerlund was soon appointed director of production engineering for all General Motors plants. His work included design for new plants, selection of equipment, floor space arrangement, and the general setup essential for a smooth flow in production. All requests for capital expenditures came over his desk and a large group of specialists worked under his direction. The duties of his office expanded with the growth of General Motors itself. Such plants as Buick, Cadillac, Oldsmobile, Oakland, Frigidaire, and Opel (in Germany) were added and many more projects were considered but later dropped. Before each addition Wennerlund made a careful study of the new line, sometimes favoring and at other times arguing against the acquisition. "We laid out many plans in our department," he wrote at a later date, "much study was required and we had to consider so many suggestions of adding new lines. We grew and grew until at the close of the 20's there were a quarter million employes." [64]

In the hands of Wennerlund, according to his own appraisal, scientific management was simplified: [65]

> System became a fetish in many cases, [and this] resulted in losing sight of the main purpose in the detail systematization itself. When applied to large organizations, it just got so big that it was beyond handling. . . . It is now realized that system has its place only where it simplifies production routine. As a result, the systematizer-for-the-sake-of-system has been replaced by the practical man who applies system as a method of simplifying production control.[66]

One exceptional contribution toward simplification in scientific management was Wennerlund's group bonus plan, conceived as a wage incentive during 1918, when labor was scarce and production increase essential. This plan was adopted throughout the entire General Motors setup.[67] The plants were thus able to eliminate much of the high cost of handling wage

[64] *Willmar Daily Tribune*, January 22, 1940.

[65] J. Christian Barth maintains that the Taylor system only seemed cumbersome to those who did not fully understand it; that it actually cut down red tape, and was quite simple.

[66] "Simplification Is the Keynote in Production Management," in *Automotive Industries*, 61:506 (October 12, 1929).

[67] A detailed account of Wennerlund's group bonus plan is given in *Wage-Incentives, the Group-Bonus Plan*, a reprint of an address given by Wennerlund, before the Society of Automotive Engineers (Detroit, 1923).

incentives on an individual basis. "It was found," according to Wennerlund, "that some of our plants had as many as 25,000 job tickets a day, all of which had to be extended, audited and credited to individual accounts. Under the group plan we have been able to do away with job tickets, using only the in-and-out clock cards and giving credit for finished good product. This has been a great saving in clerical detail in our factories, it has cut inventories of work-in-process, and has on the whole stimulated production efficiency."[68] Primarily suitable for "repetitive work arranged in progressive production lines of sequence operations," it had as its object the speeding up of the production rate per employee, and in this it was successful.[69]

Like Barth, Wennerlund saw clearly that scientific management, when misunderstood or abused by employers, can do infinite harm to the workers. Having declared that scientific management increased efficiency at General Motors to the point where three men did the work five men had done before, he said:

I still maintain that it means progress. What I believe we need is men in the fields of finance, marketing, transportation and government, just as smart as the men who have used scientific management to remake the world. I also admit that scientific management in the hands of unscrupulous employers can be a dangerous thing for humanity. But scientific management is responsible for the shorter work day and shorter work week. Workers generally don't have to work as hard today as they did under old conditions. In the last analysis, all the abuses labor complains of could be corrected by proper management.[70]

Anyone familiar with American industry, especially its metalworking phases, needs no further reminder of the importance of scientific management, and consequently of the work of men like Barth, Wennerlund, and others who contributed to its growth. The influence of the ideas set into motion by the followers of Taylor, however, was greater than many suspect, as a look at recent war production in the United States will clearly

[68] *Automotive Industries,* 61:506.
[69] It is only fair to state that group incentive was also used under the Taylor system.
[70] *Detroit News,* November 14, 1937.

indicate. Though unevenly utilized, the dominant ideal in American industry is the application of science to production. Rejected in large measure by the French and British, scientific management was vital to the rationalization of German industry in the years between two world wars. The Soviet productive experiment, too, frankly borrowed the basic Taylor principles as means to a non-capitalistic end. Greatly increasing output, scientific management also naturally increased man's capacity for both good and evil.

OF POWER, PAPER, AND SHIPS

APART from metallurgy, engineers in Norway have recently made some of their most notable technical advances in electricity and the production of wood derivatives. It was natural that in such fields, on this side of the Atlantic as well as on the other, Norwegian engineers would assume an important role. Because of the part played by the sea in the life of the Scandinavian peoples, the same generalization also applies to engineering in the world of ships. One looks for concrete instances of the transfer of Norwegian techniques to the American scene. The influence of the immigrant engineers proves to be considerable, especially in the paper industry, despite the relatively slight educational emphasis given everywhere—until recently—to applied chemistry; and despite the rapid hydroelectrical developments in Norway since about 1905, which have attracted many of the graduates of the engineering colleges. The recentness of much of the work of Norwegian engineers in American paper production and electricity, however, makes for extreme difficulty in viewing it in proper perspective at present.

I

Though the early engineers who migrated to America had no strong tradition in the field of electricity, they nevertheless included one pioneer in the development of radio. Anders H. Bull invented a tuning system for radio signals in 1899, before Marconi had succeeded in developing selective transmission. Bull, eager to make his discovery known, described it in an English periodical. The young inventor declared that, if his system were used, "The possibility of messages being inter-

cepted by stations for which they were not intended will be almost precluded, and independent signalling may be carried out between a considerable number of stations lying within the sphere of influence of each other's waves, while several despatches can be transmitted simultaneously without their being affected the one by the other."

Bull went on to explain:

> For this purpose the signals are conveyed from the transmitters to their corresponding receivers exclusively by the aid of series of impulses, each series consisting of a certain number of short wave impulses following each other at predetermined intervals of time. By suitable choice of these intervals the impulses can be arranged in series of different form. Now it is possible to tune each transmitting and receiving pair for its own special form of series in such a way that the transmitter only dispatches series of this special form, and the corresponding receiver only responds to series of the same form.

It made no difference where the various transmitters and receivers were placed, whether they were together or separate. The apparatus of each was entirely independent of the others. "Any station is, therefore, capable of sending several different messages as well as of receiving some and sending others, at the same time."[1]

Bull, after his graduation from Christiania's Technical College in 1895, had gone to Germany; he found work there, and took a supplementary course in electrical engineering in the famous engineering school at Hanover. Returning to Norway, he had instruments prepared by the Elektrisk Byraa at Christiania. In 1903 he set out for England to demonstrate his tuning system before representatives of the Marconi Wireless Telegraph Company. In response to a request by the editor of *Electrician,* he described the experiments, which had been conducted with a view to "proving the possibility of secretly communicating between stations and of the further possibility

[1] Anders Bull, "A Tuning System for Wireless Telegraphy," in *Electrician* (London), 46:573–575 (February 8, 1901). In a later issue of the same journal, vol. 50, p. 418–422 (January 2, 1903), Bull elaborated on his "Experiments on Selective Wireless Telegraphy." He describes two ways of "rendering messages unintelligible to those unconcerned."

of sending messages by means of selective telegraphy to several independent receivers at the same time." His system was tested over longer distances than had been attempted up to that time. After some alterations, good results were obtained, in spite of unsatisfactory conditions and primitive equipment, and it "was possible to transmit telegrams quite faultlessly." Messages were taken by both Bull's and the ordinary Marconi receiver; the speed of transmission was the same in both cases. Bull's conclusion, based on the experiments, was that his system was "applicable for all practical purposes where it is desirable to prevent outsiders from tapping messages."[2] His conviction remains to this day unshaken.

Bull came to America in 1904 to demonstrate his radio system before the United States Navy. Had he succeeded in exploiting the invention, in all probability he would have returned to Norway or Germany. The tests were undertaken between government stations at the Highlands of Navesink, New Jersey, and the Brooklyn Navy Yard, a distance of over 30 miles, and were described by the inventor. "The field is considered a rather difficult one for experimental work, as the waves have to pass the greater part of Brooklyn; moreover, the stations are very much troubled by interference from several other wireless installations in the neighbourhood, the interference lasting sometimes without interruption for hours." Regular service between the two points was performed by means of the Slaby-Arco system, which had been provisionally adopted by the navy.

"It was decided to try our selective instruments in connection with the existing installation. . . . The voltage used . . . is 80 and 110 volts. . . . Our transmitter was only constructed for low voltage and small power. . . . In order to get good communication we had only one way left—viz., to make the receiving arrangement very sensitive." As a result the receiver was more subject to disturbances than before. The experiments were conducted, however, chiefly with an eye to the secrecy of the

[2] *Electrician,* 51:963 (October 2, 1903).

correspondence. A message, Bull wrote, which could not be read "in spite of its being repeated some four or five times with the Slaby instruments was easily deciphered when sent once by ours."[3]

The reasons for Bull's failure to exploit his ingenious device are suggested in the comments written by authorities on the wireless. J. A. Fleming, while praising the effectiveness of Bull's instruments, maintains that they were "exceedingly complicated and can only be understood by reference to very detailed diagrams."[4] Dr. J. Zenneck maintains that they gave almost perfect protection against the "picking up" of messages and atmospheric disturbances but "their complication limits these apparatus to certain special work."[5] Marconi, writing to Bull on January 12, 1933, said, "My opinion was that the coherer receiver then in general use at the time of the tests was not capable of a sufficiently high speed of reception to allow of the employment of your apparatus with any advantage."

Bull's method, as we have seen, was based upon transmitting each signal not as a single discharge but as a series of periodic discharges that came at certain fixed regular intervals. This system was later worked out successfully by Adam Paulsen, in Copenhagen, who used different wave lengths and continuous wave tuning. Bull himself now feels that he should have continued with work in radio, because of its tremendous importance today. Marconi, whom he knew well, offered him a position in London at the time of the first tests, but this offer, together with another for the invention itself, was rejected. Writing much later, Marconi summed up Bull's work in these words, "Your apparatus was an interesting and ingenious contribution to the problem of obtaining secrecy in wireless communication, and worthy of being preserved in the Museum."[6] The museum referred to is the Science Museum at

[3] Bull, in *Electrician*, 54: 142 (November 11, 1904).
[4] "Telegraph," in *Encyclopœdia Britannica*, 26: 538 (eleventh edition, 1910–11).
[5] J. Zenneck, *Wireless Telegraphy*, 332 (New York, 1915). This work was translated by A. E. Seelig.
[6] Marconi to Bull, January 12, 1933, a letter in the possession of Anders Bull.

South Kensington, England, where Bull's original sender is now preserved. The receiver is in the Norsk Teknisk Museum at Oslo.

In the several years that followed Bull's attempt to interest the navy in his radio, he remained in this country, working part of the time in the navy yard at Brooklyn. During 1907–08 he assisted, in Norway, Professor Kristian Birkeland, co-inventor of the process for producing synthetic nitrates, and consultant for Norsk Hydro, which exploited Birkeland's discovery. When Bull returned to America, he was, as we have seen, destined for a new career in the development of subway and tunnel transportation.

Another of Bull's contributions in electricity that is worthy of mention was his fog signal system, invented in 1918, by which it is possible accurately to determine the compass direction from which signals are coming. The direction is obtained from the pitch—four rising and four falling pitches, for example, being due east. Bull's equipment was intended for small craft which could not afford expensive apparatus, and the one requirement of the listener was that he have an accurate sense of pitch.

In this case, as with the wireless, Bull was his own champion. Writing in the London *Engineer* in 1921, he explained that usually the direction of sound is determined by comparing the intensity of the sensations in each of the listener's ears. Our sense of intensity, however, is extremely crude, while the differences to be judged are often very slight, and secondary effects are produced that may throw the balance to the wrong side. Bull got around this defect in aerial fog signaling by applying an acoustic principle, "the salient feature of which is that the direction of the signals is determined from their pitch, a quality entirely apart from their intensity, and governed only by the rapidity of the sound vibrations. . . . The author's device may be worked with any of the sound sources in use at present, such as whistles, horns, sirens or bells, without shortening their range. No receiving instrument is used, and no code has to be

consulted for the interpretation of the signals, the rules being simple and easily memorized."

The signals in Bull's system were produced in groups of four or eight, the signals of a group following each other at equal time intervals and being all of the same duration. "To an observer listening to such a group, the individual signals will, as a rule, be partly of rising and partly of falling pitch. By counting the number of either kind he will be able to determine in what direction of the compass the signalling party is situated. This result is accomplished by means of what may be called a polarisation of the signals, the latter being endowed with properties depending altogether on their direction." Tests were made in a suburb of Chicago during the winter of 1920–21; in the inventor's mind they were successful.[7]

Bull successfully demonstrated his system to the United States Coast Survey and Lighthouse Service in 1922, but it was not adopted. He maintains that the coastal protective system had no proper means to experiment satisfactorily at the time of the test, and he is of the opinion that directive fog signaling by means of polarized sound would be satisfactory today.[8]

II

Some of the electrical and mechanical engineers who preceded Anders Bull in America also made lasting contributions in the electrical field. Georg Gustavsen, a Horten graduate, invented special machines used in the mass production of radio and movie sound apparatus.[9] Charles W. Borgmann, who came in 1900, after graduating from Christiania's Technical College, has been in charge of the development of manual equipment with the Bell Telephone Laboratories. In 1930 he was one of five engineers sent to Europe to study communication as it is

[7] Anders Bull, "Fog Signalling by Means of Polarised Sound," in *Engineer* (London), 132:505 (November 11, 1921).

[8] Interview, May 21, 1941. For more information about Anders Bull, see *Who's Who in Engineering,* 180 (New York, 1937), and an article by Magnus Bjørndal, in *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 11 (November, 1935).

[9] *75 års biografisk jubileums-festskrift, Hortens tekniske skole,* 176.

practiced there.[10] Andrew H. Bakken, another Horten graduate, joined the Westinghouse Company in 1902 and was responsible for innumerable electrical developments, recently receiving the Westinghouse silver medal for outstanding work.[11]

Jacob K. O. Anthonisen had a varied career in the New World, but his chief work was in hydroelectric and water-power developments. A graduate of Trondhjem's Technical College, he was associated with Halfred Hoyem in the design of several hydroelectric stations for the Montana Power Company. From 1922 until his death in 1938, Anthonisen was associated with the St. Anthony Falls Water Power Company in Minneapolis, a concern that furnishes power to the flour mills and the Twin City streetcar system.[12]

Theodor Schou, following a technical education received at Christiania and Dresden, left for the United States in 1903, as did Anthonisen. After working as engineer with several leading electrical concerns, he became consultant for Fairbanks, Morse, and Company at Beloit, Wisconsin. Schou has been a prolific author of technical papers and has a notable record in connection with flywheel recommendations for direct-connected synchronous motors to compressors, flywheel recommendations for successful parallel operation of direct-connected alternators to Diesel engines, and the successful development of two-core synchronous indicator-type frequency changers.

Several Norwegian engineers have won the Coffin award of the General Electric Company. Ludvig S. Walle of Schenectady, a graduate of Bergen who also studied at Dresden, was thus honored in 1924 after service with the company dating back to 1904. Of special interest among his many inventions were those in the field of automatic power stations. Andrew Halvorsen was awarded the same prize in 1936.[13]

Thorleif Bjerke Paulson, designing engineer with Chas. C.

[10] *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 21 (November, 1935).

[11] *Nordisk tidende,* June 25, 1942.

[12] *Norwegian-American Technical Journal,* vol. 3, no. 2, p. 13 (August, 1930) and vol. 12, no. 1, p. 19 (July, 1939); *Decorah-posten,* February 22, 1938.

[13] *Nordmanns-forbundet,* 29:156 (1936).

Moore and Company of San Francisco, won a reputation on the Pacific coast designing and testing steam electric power and pumping stations. Among his more important projects were the power plants of the Long Bell Lumber Company of Longview, Washington; the Power River Company in British Columbia; the Consolidated Mining Company of Trail, British Columbia; and mining companies of Arizona and New Mexico. Paulson came to America a year after completing his training in mechanical engineering at the Christiania college in 1905.[14]

Torleif Sverre Norbom, an able mechanical engineer from Horten, did his work in the East. As chief designer with the S. Morgan Smith Company of York, Pennsylvania, he was responsible for planning considerable hydroelectric equipment. His outstanding job, perhaps, was the water turbines used in the Bonneville Dam project, which was hailed as the largest of its kind in the world. North of the American boundary, Sven Svenningson, after a successful career in the States, became chief engineer of the Shawinigen Water and Power Company of Montreal in 1919. A graduate of Christiania's Technical College, Svenningson came to America in 1909. His premature death in 1934 deprived Canada of one of its leading hydroelectricians.[15]

The Latter-day Saints have a colorful figure in Marthinius A. Strand of Salt Lake City, owner and manager of the Strand Electric Service. Strand not only has done much of the lighting for Mormon buildings in Utah, but he also took out the basic patent on the automatic stop for phonographs, which he sold to the Edison Company; the invention is now widely used. He was the inventor of long-line and other testing equipment that has been adopted and used by the Bell Telephone System everywhere, and of a remote-control switch adopted and manufactured by the Cutler-Hammer Company. In the course of his regular work, he did the electrical engineering and installation

[14] American Society of Mechanical Engineers, *Transactions*, vol. 54, record and index, p. 73 (1932); *Minneapolis tidende*, November 10, 1932.

[15] *Skandinaven*, September 7, 1934; *Minneapolis tidende*, August 30, 1934.

for the naval ammunition depot at Hawthorne, Nevada, and at Boulder Dam; and the installation of substations and transmission lines for the Southern Nevada Electric Company, to mention only several of his many technical undertakings. Strand is interested in winter sports; he introduced skiing in Utah and the surrounding states. His technical education was received at Porsgrund, at an evening school in Christiania, and at the institute in Darmstadt. He came to the United States in 1910.

Johannes Bernt, who is estimating engineer for the New York office of the General Electric Company, has estimated the electrical requirements of such buildings as the Radio City Theater, Banker's Trust, the Biltmore, the Woolworth, the Empire State, the Municipal, and the Metropolitan Square Theater. Bernt is a graduate of the Mechanical Trade School at Porsgrund and the Mittweida Polytechnicum in Germany; he came to America in 1902. Returning to Norway in 1914, he became manager of a factory at Skien that supplied his homeland with vital electrical equipment during the First World War. He returned to the United States in 1925.[16]

Among the many electrical engineers who were born and partially educated in Norway was Svend E. Johannesen, a pioneer in the development of transformer engineering. A graduate of the Rose Polytechnic Institute of Terre Haute, Indiana, Johannesen became associated in 1902 with the Westinghouse Electric Manufacturing Company in Pittsburgh, where he designed transformer equipment for the New York interborough subway and the New York, New Haven, and Hartford Railroad. He joined the General Electric Company in 1906 and lived until his death in 1944 at Pittsfield, Massachusetts. In 1926 he was awarded General Electric's Coffin medal for his work in developing the distribution transformer.[17]

All of the engineers described thus far in the chapter came to America not later than 1910. They constitute a small stream

[16] Magnus Bjørndal, in *Norwegian-American Technical Journal*, vol. 13, no. 1, p. 12 (December, 1940).

[17] *New York Times*, December 23, 1944.

of immigrants that started about 1893. In 1923 a new group of engineers began to appear on the American scene. Many were graduates of the Institute of Technology and of the school at Porsgrund; some of the latter had taken advanced work in electricity at a German institution. Perhaps the brilliant young men of this recent group have not as yet made their larger contributions, but the record to date is impressive.

Magnus Bjørndal, proprietor of the Tech Laboratories at Jersey City, is the inventor of an automatic gear shift, an electric hydrometer, a new automatic indicating and controlling viscosity meter, an automatic direction finder, a submarine locating device, and an automatic cap-type moisture meter; and he is co-inventor of an oscillating electric heater. When serving as chief engineer for the Daven Company of Newark, New Jersey, 1931–35, Bjørndal developed a new line of test and control instruments for broadcasting stations and designed all controls for the Radio City installations of NBC. In recent years he has invented, designed, and manufactured numerous scientific and technical instruments, besides serving as consulting engineer and registered patent attorney. Every ship of the United States Navy carries electrical equipment designed by Bjørndal.[18] Bjørndal is a graduate of the Mechanical Trade School at Porsgrund, 1920. He pursued further study in mechanical and electrical engineering at the Hindenburg Polytechnicum in Oldenburg.

Finn H. Gulliksen, a product of the Institute of Technology at Trondhjem, has specialized in voltage regulation and synchronizing development, design, and application. In 1934 he was awarded a prize by the American Institute of Electrical Engineers for one of the two best papers submitted in that year.[19] Bjørn Jore, a graduate of the same school and an electrical engineer for the Anaconda Wire and Cable Company, was responsible for the cable layout and design in the power distribution at Ford's River Rouge plant; he also invented a shielded

[18] From materials in archives of the Norwegian-American Technical Society, Chicago, and information supplied by Bjørndal.

[19] *Aftenposten* (Oslo), September 12, 1934.

terminal for rubber cables. A. E. Thomassen, of the Phoenix Engineering Corporation of New York City, had a significant part in the electrification of the Delaware, Lackawanna, and Western Railroad. This was the first instance of a 3,000-volt D-C installation with Mercury-arc rectifier substations on so large a scale, and the undertaking was completed in the record-breaking time of two years. Thomassen graduated from the Bergen school in 1924 but continued his formal technical education in America.

Of the younger men few have shown greater promise than Sigurd J. Stockfleth, another graduate of the Oldenburg Polytechnicum, whose work with the Bell Telephone Laboratories in New York since 1929 has resulted in the invention of multi-contact switches, relays, dials, timing devices, and crossbar switches, on which he holds patents. According to the *Norwegian-American Technical Journal,* he was engaged during 1936–38 in the design of remote-control equipment for transport aviation radio and the mechanical design of airplane direction finders, as well as radio equipment for the navy.[20] Stockfleth also introduced the first multi-wound, paper-filled coil winding development, a method now widely used in the telephone industry. The crossbar switch, various features of which he perfected, is the heart of the new and improved telephone system which is replacing the present panel one. He recently designed a less costly crossbar switch which is now being adopted, and a new step-by-step telephone contact bank that will be used in the automatic telephone systems of smaller communities. He was also intimately associated with the development of the quiet telephone calling dial used in new combined handsets.

While not a few engineers have at times been engaged in welding work of one kind or another, the outstanding pioneer in this field is K. L. Hansen, consulting engineer of the Harnischfeger Corporation of Milwaukee. He came to the United States in 1901 and later attended the University of Illinois.

[20] Vol. 12, no. 1, p. 12 (July, 1939).

Hansen moved from the Westinghouse Manufacturing Company to the Louis Allis Company of Milwaukee, where he designed A-C and D-C motors and generators and became chief engineer. In 1921 he severed this connection to become a consultant. Working independently, he invented and designed the Hansen arc welder, now made and marketed by the Harnischfeger Corporation. He has since developed a number of arc-welding processes and also has patents on self-starting induction and compensated induction motors. While working for Westinghouse, Hansen conceived an idea that made it possible to eliminate uneven work and simplify the entire welding process. Though his best years have been spent in improving the welder, Hansen feels that his important future work will be with the electric motor.[21]

III

Johannes (Jack) Andersen left his home at Sandefjord in 1882, at the age of fifteen, and turned up in the United States in the next year. Later he became Swedish-Norwegian consul in New York City and was associated with the Norwegian Wood Pulp Company, importers of pulp and cellulose. In 1909 he founded Johannes Andersen and Company, largest importers of Scandinavian tree products in America.[22] Thus a Norwegian product vital to American production came with the immigrant to the New World.

Far more important, however, was the link forged between the two countries by the skills of the Norwegian engineers who developed the forest products of America itself. Their work was essentially although not exclusively a chemical one, in which the methods used in Norway, when brought to this side of the Atlantic, either were directly applied or provided a necessary background of experience for the engineer-chemists who took the leading roles.

The most famous of these men was Dr. Viggo B. Drewsen,

[21] *Electrical Engineering,* 59:518 (March, 1940); *Modern Industrial Press,* April, 1940; *Nordisk tidende,* June 25, 1942.

[22] *Nordisk tidende,* January 26, 1922; *Nordmands-forbundet,* 20:116–118 (1927).

who was educated at the national university in Christiania and at Wiesbaden and Munich in Germany. At the university in Munich he was awarded the degree of doctor of philosophy in chemistry. There, in 1881, Drewsen's research project, under the famous Professor Adolf Baeyer, was the synthesis of indigo, or a method of making artificial indigo; the process was patented by Drewsen and Baeyer in the next year. After this, Drewsen's best known early work, he became a teacher of chemistry at Trondhjem's Technical College, where he remained until 1887 and made the transition from "pure" science to the applied field of chemical engineering. Disappointed over his failure to receive a professorship, Drewsen left the college and took employment with the cellulose mills in Bøhnsdalen. There he began a vigorous study of cellulose and paper manufacture, and, with his brother Aage, took out his first cellulose patent.

After a brief but productive period as chemist at Bøhnsdalen, Viggo Drewsen left, in 1894, for the United States, following Aage, who had gone on ahead; his purpose, in part, was to take out a number of American patents. Viggo at once became superintendent of the Glens Falls Paper Company mills at Fort Edward, New York, but he shortly opened a private consulting office, the Drewsen Company, in New York City. After having been a "retained chemist" for the West Virginia Pulp and Paper Company, he spent the last twenty years of his life, from 1910 to 1930, as director of the research laboratories of this firm.

When Drewsen went over to industry, his name appeared less frequently in the learned journals, but a record of his remarkable work with paper is left in his many patents. In addition to those relating to his indigo synthesis, the total in the United States was 43, in Norway 9, and in Germany 5. When Drewsen went to Bøhn he found that there, as elsewhere, the mills did not utilize the sulphurous acid which escaped with the gases produced in cooking cellulose. He devised a method for collecting and leading the gases into a new boiling acid,

thereby getting a more durable product than was produced by earlier processes; he not only saved sulphur but also decreased the cooking time and improved the quality of the cellulose mass, making it, among other things, more susceptible to bleaching than the former product. Several Scandinavian firms bought rights to this process; in the United States it was introduced under the name "Drewsen reclaimer" and was used in more than thirty mills. Subsequently all sulphite cellulose mills in the world made use of Drewsen's innovation.

The cooking of sulphite cellulose is based on the application of calcium bisulphite in the boiling acid. At Bøhn Drewsen made a successful attempt to apply sodium bisulphite. He mixed sodium sulphate (glauber salt) with the boiling acid and obtained a change of base. In spite of the originality of his method, it proved to be not entirely practicable. In later years Drewsen worked with a monosulphite process, using sodium or magnesium as a base; this process he regarded as his greatest accomplishment. At Bøhn he also made several successful attempts at bleaching cellulose with permanganate.

The impure liquor used in the sodium and sulphate cellulose mills is gathered up (calcined) and put back into the boiling process again. The sulphite mills, by contrast, with few exceptions let the waste cooking liquor run into the sea, thus losing both lime and sulphurous acid. Most important, in thus letting the liquor go to waste, the mills lost valuable organic constituents. The search for a suitable method of using the sulphite waste therefore occupied many engineers, and among them was Drewsen. A patent of 1891 describes his method of recovering the sulphurous-acid excess by precipitating it with lime while hot and then treating the precipitate with sulphurous acid; in this way Drewsen got a calcium bisulphite solution that went back into the cooking process. A fractionated lime precipitate is now a reality in America, a proof of Drewsen's foresight. In later patents Drewsen proposed methods for the recovery of the organic materials in the liquor, for the preparation of acetone, alcohols, and other products. Two of his ideas

were later developed by others. Drewsen, however, finally concluded that the time had not arrived for an organic chemical industry based on sulphite liquor. In the meantime it would have to be utilized as fuel.

The steady depletion of our forests and the resulting rise in wood prices have caused engineers to look about for cheaper fiber materials. By 1903 Drewsen had devised a method for the production of paper from cornstalks, straw, and sugar cane. At the Cumberland Mills he produced his new fiber material at a cost 10 dollars per ton less than that of lye cellulose made from wood. Though the process received wide publicity, it has not yet been extensively used in this country, chiefly because of the great cost involved in collecting, shipping, and storing the bulky raw material. But when the forests of North America are exhausted, cornstalks and straw may well come into their own in the production of paper.

Drewsen also spent considerable time developing a pentasulphide cellulose process. This was based upon the idea of using lime and an excess of free sulphur in the boiling of cellulose — an interesting process that is both cheap and effective, but which has the disadvantage of throwing off an offensive odor. As the years passed, Drewsen became increasingly convinced that eventually cellulose cooking would have to be based upon the application of monosulphites. He took out a series of patents dealing with the preparation of suitable monosulphite solutions with sodium and, alternately, magnesium as base, as well as for the regeneration of the waste liquor. In order to apply these relatively expensive bases for the cooking of cellulose, it is necessary to regenerate them. Drewsen's accomplishments in this field should be of great value in the future.

Several other Drewsen contributions are worthy of note. During the First World War he worked on sulphite and sulphate cellulose to make them more useful for nitrating, as a substitute for cotton linters. He also proposed to collect carbon dioxide from the tops of acid towers in sulphite mills and to

use it for cooling the acid, as well as to deprive the flue gases of their carbon dioxide, which by this method would be turned into "dry ice." Finally, for Norway his work is significant in that his experiments of 1898–99 gave impetus to the introduction of mechanical pyrite burners, which made it possible to use a cheap native pyrite instead of imported sulphur.[23]

The direct application of Norwegian methods of cellulose and paper manufacture is even more apparent in the work of Olai Bache Wiig, who produced the first sulphate pulp in America and the first kraft paper made from domestic pulp. Wiig, like Drewsen born of a family associated with the paper industry, came to the United States in 1903, after receiving a technical education at the engineering school in Zwickau and working for two years in the Norwegian paper industry. He soon began improving on the processes used at the Mount Tom Sulphite Pulp Company, and served as consultant with the York Haven Paper Company in Pennsylvania and the Laurentide Paper Company of Quebec. While employed in a large pulp organization, 1907–10, controlled by George Van Dyke, he converted a soda mill at East Angus, Quebec, to the sulphate process. It was at this mill, too, that he pioneered in the production of kraft paper.

Bache Wiig began a new venture in 1910, when, in response to urgent requests, he moved to Wisconsin and promoted the Wausau Sulphate Fibre Company. He built a pulp and kraft mill with a daily capacity of 30 tons at Mosinee and had it in production within one year. It was there, too, that he first put into operation an improved kraft machine that made paper at the then phenomenal speed of 1,000 feet per minute. His paper soon became widely known and its quality recognized wherever great strength in the product was desirable. Wiig,

[23] The writer is especially indebted to S. Schmidt Nielsen's memorial speech, October 13, 1930, discussing Drewsen's technical career, before Det Kongelige Norske Videnskabers Selskab, in *Forhandlinger*, vol. 3, no. 25, p. 95–103 (Nidaros, 1931). This account includes a full list of Drewsen's patents. Also useful are an account by Eyvind Bødtker, *Viggo Drewsen, 1858–1930*, a reprint from *Tidskrift for kjemi og bergvesen*, no. 10, 1930, S. T. no. 200; *Minneapolis tidende*, May 20, 1930; *Morgenbladet*, May 20, 1930; and *Nordmands-forbundet*, 23:375 (November, 1930).

in addition to acting as general manager of this undertaking, was much in demand as a consulting engineer, and he designed and built sulphate mills at Ocean Falls, British Columbia, and Bogalusa, Louisiana. His last major work was the organization of the Tomahawk Kraft Paper Company, which took over and remodeled a mill at Wisconsin Dam. S. B. Bugge, a Horten graduate who had also been employed by Van Dyke, acted as director of the new enlarged mill and Bache Wiig was its president at the time of his death in 1925.[24]

Frequently, too, one or another of the chemical engineers in Norway has traveled to these shores to interest American capital in his improved methods of obtaining wood derivatives. Such was the case with Helmer L. Blengsli, who lectured before the Norwegian Engineers' Society of New York in 1928 on the subject, "The Wood Distilling Industry." He had built, as a consulting engineer, a number of plants in Norway employing the techniques that he had patented. At the time of his lecture, Blengsli was striving to revive the hardwood distilling industry, which in 1925 had suffered a sharp blow in the discovery by Germans of a synthetic method of producing methanol (wood alcohol). After extensive research in the laboratories of Norway's Institute of Technology, he had succeeded in discovering not only new methods of distilling hardwood, but new products. He was unable to interest Norwegian capital in his techniques and equipment, and he had come to the United States, where, he assured his listeners, he had been well received by American industry.[25]

IV

As important in the pulp industry as chemical processes is the preparation of logs after they have come downstream or by rail to the pulp and cellulose mills. Some years ago rotary knives were employed to remove the bark. Today practically all mills use the barking drum, which was invented by a graduate

[24] American Society of Mechanical Engineers, *Transactions*, 47:1310 (1925); *Milwaukee Journal*, January 25, 1925; *Minneapolis tidende*, February 5, 1925.
[25] *Norwegian-American Technical Journal*, vol. 1, no. 4, p. 7 (December, 1928).

of Christiania's Technical College, H. W. Guettler. He designed and installed his first drum for the Escanaba Pulp and Paper Company in Michigan; this was based upon an original invention of 1915, which he patented jointly with O. L. Berger. The action of the drum is relatively simple. Logs are fed automatically into one end and the drum revolves, producing friction between them. The water that is present in the drum causes the bark to peel off easily, and instead of being washed away, it is reclaimed. The logs, discharged at the opposite end, are sent back if they are not entirely free of bark.

Later perfected by additional improvements, the Guettler barking drum came into universal use in this country and elsewhere. Besides removing a serious bottleneck in the pulp industry, it saved about 10 per cent of the wood formerly lost, as well as a tremendous amount of labor. The American Barking Drum Company was formed in Chicago in 1915. A year later Guettler, together with Berger and others, organized Fibre Making Processes, Inc., which, entirely owned by Guettler since 1919, also handles other machinery of Scandinavian and American origin. But its chief product has been the U-Bar Barking Drum, now made in all sizes.[26]

One of the best known engineers in the cellulose field today is Dr. Carl Busch Thorne, vice-president of the Canadian International Paper Company and head of the famous Kipawa Mill in Quebec. After receiving a thorough technical education in the Hanover and Dresden schools, Thorne worked for a time with Drewsen, but from 1903 was engaged by the Riordon Pulp and Paper Company (later the Canadian International Paper Company) at Hawkesbury and Merritton, Ontario. At first chief engineer and sulphite expert, he was later made manager of manufacturing; since 1910 he has been technical director of this company. At the Ontario mills he produces both paper and sulphite pulp, bleached and unbleached. In 1918–19, Thorne planned and built in the wilderness of Quebec the town of

[26] *Norwegian-American Technical Journal,* vol. 1, no. 2, p. 3 (May, 1928); and information received directly from Guettler.

Temiskaming, with a population of 3,000, and the Kipawa Mill, with an annual capacity of 120,000 tons of rayon sulphite.

In the paper and rayon industries few have had a greater all-round influence than Thorne. His patents in the United States alone comprise a barker, a mixing machine, a fiber loss indicator, a fiber recovery system, and other mechanical devices; they also include a sulphite cooking process and innovations in bleaching. His chief study has been the bleaching of cellulose and it was he who introduced the bleaching process in his mills. According to *Skandinaven,* 1,000,000 tons of cellulose were bleached each year in the 1930's by the Thorne method, which is now used in Europe as well as in America.[27] His inventions have contributed notably, too, to the improvement of cellulose quality. At the time the Kipawa Mill was set up, Thorne organized a research unit to discover the most satisfactory methods of producing cellulose; one of the most modern of its kind, this organization is vital in Canada's industrial life. Kipawa cellulose is regarded today by rayon factories as among the world's finest.[28]

Norwegian engineers naturally gravitated toward paper production centers in the New World. J. N. Bodtker, a graduate of Christiania's Technical College, recently became plant engineer of the Lake St. John Power and Paper Company at Dolbeau in Quebec. J. K. A. Henning, a product of Porsgrund and Horten, was engineer and chemist with the Cushing Pulp Company of St. John, New Brunswick. Petter J. Mürer, a graduate of Christiania, is superintendent of the Kipawa cellulose plant at Temiskaming; and Sigmund Wang, who studied in Christiania and Darmstadt, is manager of the same company's laboratories at Hawkesbury, having been associated with the development of wood cellulose for rayon, transparent paper, and plastics. J. B. Jensen, a graduate of the Trondhjem college, was chief engineer for the Riordon paper mills from 1907 to

[27] August 14, 1936. His patents totaled 29.

[28] *Skandinaven,* August 14, 1936; *Nordmanns-forbundet,* 25:127 (1932), and 29:257 (1936).

1910, but returned to Norway. Dr. Bjarne Johnsen has been in charge of a cellulose and paper factory at Erie, Pennsylvania, for years. Hans P. G. Norstrand, a Bergen graduate, after first serving as manager of a paper mill at Greenwich, New York, became president of the Saranac Pulp and Paper Company, the Saranac River Power Corporation, and the Norstrand Manufacturing Company, all of Plattsburg, New York. He has become known for the manufacture of paper dishes, pie plates, and similar products made of molded ground paper. Finally, though by no means exhausting the list, is C. Bache Wiig, a graduate of Christiania's Technical College. Before his death in 1922 he directed a plant at Canton, North Carolina, that really made paper of wheat straw and cornstalks, in accordance with Drewsen's formula.[29] It would be necessary to add to these a small army of draftsmen and mechanical and electrical engineers to get anything like a complete picture of the work of Norwegians in this branch of engineering, the importance of which is steadily increasing.

V

Apart from Lysholm and the Fougners, the number of Norwegian engineers who made significant contributions in the world of ships is relatively small, despite a strong native tradition in this field; and of those who must be considered, several acquired their technical education on the job or in American educational institutions.

In shipbuilding circles the name of Haakon Norbom is a familiar one. A graduate of Horten's Technical School, Norbom came to America in 1887. Once chief engineer and superintendent of the George V. Cresson Company in Philadelphia, he started his own firm in 1907, the Norbom Engineering Company. This company was soon the largest of its kind in the production of hydraulic dredging machines. Norbom organized

[29] *75 års biografisk jubileums-festskrift, Hortens tekniske skole,* 192; *Nordmanns-forbundet,* 26:96 (March, 1933), and 15:482 (1922); Alstad, *Trondhjemsteknikernes matrikel,* 159; *Minneapolis tidende,* December 10, 1930; *Norwegian-American Technical Journal,* vol. 3, no. 2, p. 10 (August, 1930).

the Pennsylvania Shipbuilding Company in 1915 and served for several years as its president; he was also managing director of the Pusey-Jones Shipbuilding Company at Wilmington, Delaware, 1916–18, while it was in the hands of Hannevig.[30] On the Pacific coast, Nils A. Christoff, who was apparently self-taught, organized in 1911, with J. F. Duthie, a shipbuilding firm in Seattle. Beginning with simple machine shops and concentrating on small boats, the company grew in size and was soon putting out steel ships at Harbor Island. As vice-president and chief engineer of machinery, Christoff was technical director until his death in 1920.[31]

Among naval architects a prominent figure is John Trumpy, president of John Trumpy and Sons at Camden, New Jersey. Educated at Bergen and Charlottenburg, Trumpy founded the Mathis Yachtbuilding Company in 1909 as part owner. Since then he has been busy designing and building yachts and motorboats, acting as naval architect and general manager until recently, when he became president. The firm name Trumpy was adopted in 1941. Before the recent war he produced, among other craft, about 30 speedy pursuit and patrol boats for the federal government and a number of 220-foot cruisers specially designed for Florida waters. During the war he built at least 30 submarine chasers and was engaged in the construction of many patrol boats as well as other craft. Grandson of a famous Bergen shipbuilder, Trumpy learned about ships, especially wooden ships, in his native Hansa city; and his preference for wooden craft, such as his grandfather had produced at Bergen, is shown by the fact that as shipbuilder he concentrated on cruising yachts, with motors, ranging in length from 60 to 120 feet. No less than 250 yachts, which are famous along the east coast, came from his plant, among these being the presidential yachts for Harding, Coolidge, and Roosevelt. It was Trumpy's eager hope that after the war he might return

[30] *Norwegian-American Technical Journal,* vol. 10, no. 1, p. 5 (February, 1937); *Minneapolis tidende,* April 13, 1933.

[31] *Washington posten,* June 25, 1920.

to building his favorite type of ship. He was awarded the Navy E as a recognition of the efficiency of his war work.[32]

Three men among many on the west coast—Toralf Østbye, Axel Wærenskjold, and Jens Heyerdahl Hansen—have names prominent among shipowners. Østbye, a graduate of Trondhjem's Technical College, served on the engineering staff of the Seattle Construction and Drydock Company and the Todd Dry Docks, and set up his own business in Seattle, in 1916, as marine surveyor and consulting engineer. He was also surveyor for Det Norske Veritas and after 1917 average surveyor for the Norwegian and Swedish Marine Underwriters in the Washington-Oregon-British Columbia district. During 1919–23 he was engaged in the salmon canning and other fishing industries in Alaska and the state of Washington.[33]

Axel Wærenskjold, who is vice-president of the Norwegian-American Historical Association, studied machines and machine designing in Chicago after leaving Norway in 1883. He made a reputation in the San Francisco area, first as chief engineer with the Hercules Gas Engine Company, then as directing genius of his own firm—the Atlas Gas Engine Company—after 1904. When his plant burned at the time of the San Francisco earthquake in 1906, he moved his business to Oakland and soon made it known the world over. In 1916 he combined Atlas with the Imperial Engine Company to form the Atlas Imperial Engine Company; in the same year he began to produce Diesel engines for ships. Whole fleets of west coast ships were equipped with engines at his plants, and branch offices were maintained the world over. Recently he sold his business interests.[34]

Heyerdahl Hansen, a graduate of the Technical Institute at Charlottenburg, was chief engineer with the Pelton Water

[32] Wong, *Norske utvandrere,* 152; archives of Norwegian-American Technical Society, Chicago; *Nordisk tidende,* November 25, 1943; information supplied by Trumpy.

[33] Alstad, *Trondhjemsteknikernes matrikel,* 193; archives of Norwegian-American Technical Society, Chicago.

[34] *Sønner av Norge,* 34:335 (December, 1937); *Nordmands-forbundet,* 24:219 (1931); interview with Wærenskjold, August, 1940; *Nordisk tidende,* December 23, 1943.

Wheel Company of San Francisco before becoming president and general manager of the Pacific Diesel Engine Company of Oakland, a firm which he founded in 1915 and with which he was associated until 1927. Hansen won a gold medal at the Panama-Pacific International Exposition in 1915 for the design and construction of a 20,000-horsepower turbine exhibited by the Pelton Water Wheel Company; he further identified himself with west coast shipping through the Diesel engines produced by his own firm.[35]

VI

Perhaps the greatest name among Norwegian-American naval engineers is that of Rear Admiral Peter C. Asserson. When he was sixteen he shipped as a cabin boy on a bark leaving Stavanger and sailed to the Mediterranean and Black seas. He soon became captain of merchant ships sailing from German, English, and Scandinavian ports, and in 1859, at the age of twenty, he arrived in America, intending to make his home in this country. Employed by the United States Coast Survey and Lighthouse Service, he was assigned to the Gulf of Mexico, where he participated in a hydrographic survey and assisted in erecting a large screw-pile lighthouse, Shoal Light, the first high-power lighthouse ever to be built on a shoal in the ocean as far as 15 miles from shore.

Asserson apparently planned to go up the Mississippi to settle in the Northwest Territory sought out by the Scandinavian immigrants, but the Civil War prevented him from so doing. Faced with the alternatives of a quick escape from New Orleans or joining up with the Confederate forces, Asserson found himself in sympathy with the North. Hoping to leave the South, he offered to take a merchant ship, loaded in the afterhold, to consignees in Spain. He safely delivered the ship and its cargo in spite of unequal ballast and the necessity of running the blockade that Union ships had already set up in southern waters. He returned at once to the United States and prepared

[35] *Skandinaven*, June 10, 1927; interview, August, 1940.

for service in the navy by taking special courses in navigation, astronomy, and engineering at Cooper Union in New York City and from private tutors. Successfully passing the examinations in May, 1862, he was appointed master's mate and thereafter engaged in many of the naval campaigns of the Civil War. He was promoted to the rank of ensign, served as navigator, and was finally appointed to the civil engineer corps of the navy. From 1866 to 1868, Asserson was assigned to duty at the Norfolk Navy Yard; from 1868 to 1869 he was on coast survey duty; and in 1869 he was honorably discharged from the navy.

Asserson's first important engineering job after his Civil War service consisted of raising wrecked ships and clearing other obstructions from the Elizabeth, Potomac, Rappahannock, and James rivers. No less than four battleships, two frigates, and several river craft were brought to the surface, among them the "Merrimac" ("Virginia"), the "Cumberland" (the first federal ship to be sunk by the "Merrimac"), and the "Pennsylvania." In raising these vessels, Asserson "performed some of the most difficult feats known to marine engineering." An interesting detail of this work was the recovery, intact, of the figurehead of the Indian chief Tecumseh from the "Delaware." In the early 1870's Tecumseh was presented to the Naval Academy, where midshipmen dubbed him "The God of 2.5" (the passing grade in their studies) and still implore his favor before examinations.

In 1873 Asserson was appointed superintendent of improvements at the Norfolk Navy Yard. He also served as assistant in charge of the reconstruction of the yards, which had been all but ruined in 1865. During the next year he was commissioned as civil engineer and was put in full charge of the Norfolk reconstruction work. In ten years he transformed the mined yards into an efficient station. "Long stretches of substantially built wharves and quays replaced the old wooden ones; the dry dock was rebuilt; wet docks were built to receive timber needed for the ships of that date; and the workshops and storehouses that covered many acres of ground were erected. The streets

were well paved, and up-to-date sewerage and drainage systems were constructed." Among the many other unique features of his work was a salt-water fire system, which was the first of its kind in America and is said to have been a great success.

Asserson was promoted to captain in 1882, partly as a result of a long fight by him and others for the same privileges of promotion and rank enjoyed by line officers; three years later he was sent to the naval station at New York. When he arrived, the yard was "practically without a dry dock or wharf at which a ship could be tied up. There was only 15 ft. of water in the Wallabout Channel, the 'cob dock' and ordnance docks were being eaten away by East River tides, many of the streets were unpaved, and the big granite Dry Dock No. 1 was leaking." Asserson set to work to save parts of the cob dock by putting up sturdy sea walls in place of the existing wooden ones. The new wall was "2230 ft. long, built over solid cribwork of Georgia pine (2 by 12 in.), on which was laid a superstructure of concrete — the whole being capped with a coping of granite blocks. This piece of work was examined by experienced engineers who reported that there was not another like it in the United States."

He also installed a salt-water fire system and automatic sprinkler systems in the buildings, put up "a mammoth machine shop," new buildings, miles of railroad lines, an electric lift and power plant, and facilities for from 10,000,000 to 15,000,000 tons of coal. Two drydocks were rebuilt of concrete; these were considered remarkable because they were designed, reconstructed, and enlarged without the assistance of outside contractors. For the first dock he "built an underground electric pumping station, at that time the only one of its kind on record."

This was constructed so as to save space and was located at the head of the dock, built entirely beneath the surface, encased within a caisson or wall of cement or stone, this insuring the machinery against damage by cold, heat, or moisture. Centrifugal pumps were installed with a capacity of throwing 30,000 gal. of water per min. out of the dry dock, thus enabling the dock to be completely emptied of water in one-third the time and at one-half the cost of the

former method. This also attracted much attention in the engineering world. Dry Dock No. 3 was built under his supervision and plans were made for Dry Dock No. 4, the latter, however, was not undertaken as his retirement from the service was then about due.

Many other services and honors are associated with Asserson's name. He was called to Washington several times in the 1880's by the bureau of yards and docks as senior member of boards that were to consider navy undertakings. He was frequently sought as consultant: the stations at Mare Island, California; St. John's, Newfoundland; Port Royal and Charleston, South Carolina; Puget Sound; and Annapolis all benefited from his skill and experience. He retired in 1903, with the rank of rear admiral; at that time he was senior member of the corps of civil engineers and highly respected for his exceptional engineering skill—the product largely of self-education and experience.

Colonel Hans Christian Heg, who made history during the American Civil War as leader of the gallant Fifteenth of Wisconsin, is a figure well known to Norwegian Americans and historians alike. Asserson's name deserves similar recognition, even though his life was in many respects less dramatic. His career was one with the progressive technical and industrial development that followed the Civil War and which, in spinning out its course, revolutionized the foundations of our daily life. More specifically, he was a pioneer like John Ericsson, the Swedish inventor; he made basic contributions when our fleet was emerging from an assemblage of wood and sail to become what it is today, not only the greatest striking force in the world but also an intricate mechanism of steel, dependent as never before upon the engineering group that Asserson headed.[36]

[36] Quotations are from the excellent biography of Asserson in American Society of Civil Engineers, *Transactions*, 96:1397–1403 (1932); see also *Minneapolis tidende*, December 14, 1906; and an article by the present writer in *Nordisk tidende*, March 23, 1944.

ENGINEERS AND ENGINEERING

THE field of engineering is so extensive and its branchings are so many that only part of the story of the Norwegian engineers in the New World has been told thus far. Something of the true scope of the engineer story is revealed only when the contributions of a large number of other Norwegian immigrants are considered and their careers studied against the broad background of America's growth.

I

It is unnecessary to emphasize the importance of building materials and the industries that provide and use them. Steel and concrete have been and continue to be basic essentials in most structural lines. The activities of those engineers who helped develop the steel industry are particularly significant, and since they were also associated with bridge and other construction work, their careers have a varied aspect.

A. B. Neumann, a graduate of Trondhjem's Technical College, came to America in 1893 and became chief engineer of the United States Steel Corporation's plant at Gary, Indiana. He built a city where there had been only sand—in the heart of the famous Indiana sand dunes. He also built the plants of the American Rolling Mill Company at Middletown, Ohio, and of the Interstate Iron and Steel Company at Chicago. He became chief engineer of the Chattanooga Steel Company and a champion of the industrial future of eastern Tennessee, today a center of steel production. Though Neumann was extremely versatile, he specialized in steel-rolling mills, blast furnaces, and coking ovens. Among his many inventions, the Baker-Neumann blast furnace stock distributor is particularly note-

worthy; it is used in the furnaces of the Bethlehem Steel Company.[1]

Among the many others who contributed to the development of the steel industry, mention should be made of two Trondhjem graduates. D. A. With was associated for many years with the Illinois Steel Company as civil engineer in charge of construction. O. L. Berby migrated in 1911 and became chief engineer with the Clyde Iron Works of Duluth—producers of steel cranes, hoisting equipment, and the machinery used in lumber camps for hauling logs and loading them on railroad cars.[2]

A Horten man, C. B. Christophersen, was designing engineer with the Carnegie-Illinois Steel Corporation of South Chicago. He assisted in the planning and development of various steel mills for the United States Steel Corporation at South Chicago, Gary, and Birmingham; his chief work has been that of designing and estimating blast furnaces with full equipment such as ore-handling machinery and power stations.[3] Carl B. Moe, Norwegian vice-consul at Detroit, was educated at Trondhjem; he became chief engineer of the Iowa Steel and Iron Works at Cedar Rapids, Iowa, and manager of the De Croupet Iron Works in Detroit; at present he is part owner of the C. B. Moe Company, producers of metal building products.[4] Moe's partner, A. H. Nesheim from Bergen's Technical College, designed and promoted the Federal electric-welded solid steel window while he was chief engineer (and later vice-president) of the Federal Steel Sash Company at Waukesha, Wisconsin. This window was used in the Woolworth and Equitable buildings in New York, as well as in many industrial plants.[5]

Closely related to steel, reinforced concrete has profited in a singular manner from the skills of Norwegian engineers. Heidenreich's work—discussed in an earlier chapter—was

[1] H. O. Sundby-Hansen, in *Nordisk tidende,* January 25, 1917; Alstad, *Trondhjemsteknikernes matrikel,* 82.

[2] Wong, *Norske utvandrere,* 240.

[3] *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 226.

[4] Alstad, *Tillegg,* 68.

[5] Wong, *Norske utvandrere,* 198; *Norwegian-American Technical Journal,* vol. 1, no. 2, p. 1 (May, 1928).

closely rivaled by that of Herman Fougner, who graduated from Trondhjem's Technical College in 1897. His first experience was in the design and erection of all types of structures —chiefly steel—and of steel freight cars. In 1900 Fougner became associated with Milliken Brothers, then a leading New York steel construction firm, and he was put in charge of a contract with the Russian government for the erection of harbor works at Port Arthur. He completed a naval basin, large cranes, storehouses, and magazines just in time for the Japanese to destroy most of his work during the Russo-Japanese War. Then followed several years in South Africa and Asia during which, among other things, he introduced structural steel buildings in South Africa. Returning to America in 1905, he became head of the New York office of the Trussed Concrete Steel Company (later the Truscon Steel Company) of Youngstown, Ohio. In the next twelve years he made a thorough study of reinforced concrete and also served as a private consultant.

> Reinforced concrete was then still in its infancy. And few of the older generation of engineers and architects had any knowledge of the design or use of this material. Mr. Fougner saw the great possibilities of reinforced concrete and studied its development intensively. As a result he was recognized as one of the leading concrete engineers in the United States, and developed a large and profitable business for the products manufactured by the Corporation. . . . During the years 1909 to 1911, Mr. Fougner lectured on reinforced concrete at Pratt Institute.[6]

Fougner's firm designed many of the leading reinforced-concrete structures of the period; for example, a viaduct at Richmond, Virginia, built on a curve—then the outstanding work of its kind; the Marlborough-Blenheim Hotel at Atlantic City, with the largest concrete dome then in existence; the Traymore Hotel, also in Atlantic City; the engineering features of the buildings at West Point Military Academy; and countless other structures, including bridges and reservoirs.

During the First World War, Fougner entered into partner-

[6] American Society of Civil Engineers, *Transactions,* 96:1480–1482 (1932).

ship with his younger brother Nicolay to build concrete ships. In 1917 Nicolay had invented and constructed the first seagoing concrete ship, at Moss, Norway. The Fougner Concrete Shipbuilding Company, with a contract from the United States Shipping Board for several ships, constructed a yard at its own expense and had one ship ready when the war suddenly ended and all contracts were canceled.[7] Herman Fougner then returned to his consulting business and had charge of the construction of the great plant of the Mergenthaler Linotype Company in Brooklyn. He was active from 1922 to 1927 as a contractor; in the late twenties he formed a partnership with Raoul C. Gautier, a French engineer and architect, and was chiefly engaged in designing industrial buildings, harbor improvements, breakwaters, and swimming pools. During the last years before his death in 1932, he made a study of the engineering aspect of handling freight motor trucks at terminals and warehouses; he was also granted patents on improved methods of floor design and layout.[8]

Nicolay Fougner, also a Trondhjem graduate, made his American debut with the Trussed Concrete Steel Company and served as inspector for the Detroit River Tunnel from 1906 to 1908; but he returned shortly to Europe as chief engineer for the London branch of the same company. Transferred to the Orient, he was put in charge of all his firm's undertakings east of the Suez. He planned the 156-foot dome of the public library in Melbourne, Australia. After the outbreak of the first Russian revolution in 1917, he returned to Europe by way of Manchuria and Siberia, settling in Christiania.

Fougner had been studying the problem of ships for some years and had actually built a concrete craft, the "Buccaneer," at Manila in 1915. After his return to Norway he attacked the problem of replacing the heavy tonnage losses of the Norwe-

[7] "Building a Government 3500-Ton Concrete Ship," in *Engineering News-Record,* 81:1058–1065 (December 12, 1918).

[8] Alstad, *Trondhjemsteknikernes matrikel,* 125; *Norwegian-American Technical Journal,* vol. 6, no. 1, p. 10 (April, 1933); *Minneapolis tidende,* March 31, 1932.

gian merchant marine in the First World War. The solution, he felt, lay in concrete ships. In August, 1917, he produced the first seagoing ship of this kind in the motor-powered "Namsenfjord." Despite the prevailing notion in technical and shipping circles that it was impossible to build ships of reinforced concrete that would stand the pounding of motors and heavy seas, the "Namsenfjord" proved satisfactory in most respects. While Fougner admitted that the concrete hull was heavier than one of steel and that steel shells were better able to withstand light blows and scratches resulting from rough handling, he stated that the concrete ship had a greater cubic capacity and greater space for deck cargo. Experience also taught him that his ship was cheaper to build and maintain; it was less subject to engine vibration; and, because of its heavy hull, it required less ballast than the steel ship. Furthermore, its movement in rough seas was easier, it was more quickly repaired, was fireproof, had better insulating properties for such cargoes as ice and fruit, and was more easily kept clean.[9]

After overcoming governmental objections to the use of concrete, and building additional ships in Norway, Nicolay entered into the American partnership with his brother Herman, who in the meantime had been negotiating with the shipping board. In October, 1917, Nicolay had conferences with a newly created concrete ship section of the board, organized by R. J. Wig; the result was that the Fougners agreed to prepare a shipyard before beginning actual construction. Of a total of twelve concrete ships actually built by all firms for the shipping board, one—the "Polias"—was constructed and launched late in 1918 by the Fougner company. In addition, the Fougners built the first concrete oil carriers ever ventured, for the Standard Oil Company of New York, in the spring of 1918.[10] In 1923 Fougner went to Argentina as South American director of the Truscon Steel Company. After traveling extensively in

[9] N. C. Fougner, *Seagoing and Other Concrete Ships*, 1–6 (*Oxford Technical Publications*—London, 1922).

[10] Fougner, *Seagoing and Other Concrete Ships*, 68–85.

South, Central, and North America, he settled permanently in New York City, still employed by the same company.[11]

Outstanding among the younger men who have worked with reinforced concrete is Inge Lyse. Before accepting a professorship in 1938 at the Institute of Technology in Trondhjem, his alma mater, Lyse was employed in research work for the Portland Cement Association, both in Chicago and at Lehigh University. During the 1930's he was professor of engineering materials at Lehigh and director of the Fritz Engineering Laboratory. His publications in American and European journals describe many tests made to determine the strength of concrete in various forms. His work has been amazingly brilliant and his pen prolific.[12]

Closely related to the concrete story is the production of cement. The pioneer Norwegian engineer in the American cement industry was Andrew Lundteigen, who studied chemistry at Norway's national university in Christiania and came to the United States in 1887. First employed in the office of a Milwaukee analytical chemist, Lundteigen began his long career in cement in 1889, when he was made chief chemist of a Portland cement plant at Yankton, South Dakota. This project was one undertaken by a group of Milwaukee capitalists and was of a frankly experimental nature. Lundteigen had had no previous experience with cement; in fact, little was known in this country about its manufacture. In 1893, while Heidenreich was becoming interested in reinforced concrete, Lundteigen journeyed to Europe and visited the cement plants of England, Germany, and the Scandinavian countries, making the acquaintance of many engineers in the field. This trip was of the greatest value to the eager young man, who in 1900 accepted a position as chief chemist with the Peerless Portland

[11] Alstad, *Trondhjemsteknikernes matrikel,* 219; Alstad, *Tillegg,* 60.

[12] Contributions by Lyse for the period of the 1930's will be found in the *Proceedings* of the American Concrete Institute, the American Ceramic Society, the American Society of Civil Engineers, and the American Society for Testing Materials; in *Teknisk ukeblad, Zement, Concrete, Beton und Eisen;* in the *Journals* of the American Concrete Institute and American Welding Society; and in *Engineering News-Record* and *Civil Engineering.*

Company at Union City, Michigan, and two years later became superintendent of the same plant. Moving to Kansas City in 1910, he was first consulting engineer and later vice-president of the Ash Grove Lime and Portland Cement Company. Of his work it can be briefly said that he concentrated mainly on improved manufacture, and in 1931 he took out a patent, with an associate, on an improvement in the Portland cement process.[13]

Andrew K. Frolich, a graduate of the Ilmenau institute, was until recently superintendent of the Louisville (Nebraska) plant of the Ash Grove Lime and Portland Cement Company. He can pride himself on having designed and supervised one of the most up-to-date cement plants in the country. Following varied experiences in Norway and Russia, he came to America, largely at the urging of Lundteigen, and has been employed by the same company since his arrival in 1924. He was co-inventor of a method of returning collected cement dust to the kiln, but his chief pride is the fact that for many years his plant at Louisville has received the annual prize awarded by the Portland Cement Association for having no lost-time accidents. He is a brother of Per K. Frolich, the distinguished Norwegian-American chemist, and is now chief engineer of all plants of the Ash Grove Lime and Portland Cement Company, with office in Kansas City.[14]

Representative of others who have contributed in one way or another to the cement industry is Olav S. Corneliusen, a graduate of the Mechanical Trade School at Porsgrund and a specialist in the engineering design and machinery of cement plants. During the first two decades of the present century, Corneliusen carried out important work with the mills and machinery of the Kent Mill Company, New York; the Whitehall Portland Cement Company, Cementon, Pennsylvania; the Phoenix Portland Cement Company, Nazareth, Pennsylvania;

[13] See *Norwegian-American Technical Journal*, vol. 3, no. 2, p. 10, 16 (August, 1930); and Lundteigen's "Notes on Portland Cement Concrete," in American Society of Civil Engineers, *Proceedings*, 23:63 f. (1897).

[14] Information obtained during an interview in June, 1940.

the Clinchfield Portland Cement Company, Kingsport, Tennessee; the Kentucky Portland Cement and Coal Company, Louisville; and the Atlas Portland Cement Company, Northampton, Pennsylvania. After spending the years 1917 to 1922 in Cuba, he returned to the States to become mechanical engineer for the Dexter Portland Cement Company at Nazareth, Pennsylvania. He died in 1925, while employed in the construction of a large cement plant in Brazil.[15]

II

A number of the many engineers who worked on the railroads of this country had experience in surveying, but Lars Netland and A. M. Mosheim are peculiarly identified with this branch of engineering. Netland, soon after graduating from Trondhjem's Technical College, remodeled about 150 railway stations in Arkansas. In 1891 he was made office engineer of the Crozier Land Association at Elkhorn, West Virginia. For seven years he was associated with the development of coal land — a work involving topographic mapping and the subdivision of land into leases, the investigation of titles, considerable construction of power plants, railroads, coke ovens, tramways, roads, and the laying out of townsites and water-supply systems.

In 1898 Netland set out for the Klondike, where he indulged his love of outdoor life and engaged in a private practice of mine and claim surveying at Dawson. From 1900 to 1903 he made exploration surveys of remote parts of the Yukon Territory as chief of a party employed by the Canadian government. In the years that followed, he was employed in the same work by the United States government during its survey of the Alaska-Canada boundary. Netland's party surveyed and monumented from latitude 54 to latitude 66, and a 5-mile strip along the entire boundary was mapped. This work completed in 1910, Netland became resident engineer and superintendent for the Canadian Colleries, Limited, at Cumberland, British

[15] American Society of Mechanical Engineers, *Transactions*, 47:1319 (1925).

Columbia. There he was in charge of the development of 10,000 acres of coal land, which involved the construction of two complete towns with water-supply, light, and sewer systems; the erection of a hydroelectric project and a transmission line with substations at four mines; the creation of a standard-gauge railroad, the sinking of mine shafts, and the erection of coal tipples; and the installation of lighting systems for seven towns. In 1915 Netland was put in charge of the inventory and valuation of the Southern Pacific Company's coal mine at Beaver Hill, Oregon; in 1917–18 he was chief engineer and superintendent of the Chicaloon Coal Company in Alaska, engaged in driving prospect tunnels and putting up power-plant buildings and transmission lines. Later going to California, he made surveys and engaged in various undertakings involving water-supply and storm sewers at Oakland, Berkeley, and San Francisco.[16]

Netland's rich experience was paralleled by that of A. M. Mosheim, who was trained as an army officer as well as an engineer, and was well known as a ski jumper in Norway before his departure for South America in 1890. He was associated with railroad building over the Andes between Argentina and Chile, and when civil war broke out in Chile in 1891 he took Chilean troops over the mountains by rail. Later wounded in the fighting, he left South America by way of Argentina and returned to Norway, taking employment with the state railroads. Like Netland he was attracted to the North; he arrived at Dawson in 1898 and spent several years in search of gold. He was then employed by the Canadian government as surveyor of gold mines and in 1904 by the United States government, joining Netland in surveying the Alaska-Canada boundary. Each was head of a division and each had an assistant and five other men in his group. Their task was to draw a 650-mile line along the coastal mountains — a difficult assignment carrying them through forests, glaciers, and other rough

[16] Alstad, *Trondhjemsteknikernes matrikel,* 75; Alstad, *Tillegg,* 26; American Society of Civil Engineers, *Transactions,* 100:1701 (1935).

terrain. After six years in the North, Mosheim was ordered to the Philippines, but, disliking the climate there, he soon left. He was with the American army in the First World War, and he later took up civil engineering on the west coast.[17]

Closely allied to surveying is map making, and in this field A. J. Glerum had a distinguished career. Graduating from Trondhjem's Technical College in 1879, he came at once to America and found employment with Rand McNally at Chicago. Three years later, Glerum went to the Matthews-Northrup Works at Buffalo, New York, becoming superintendent of the map department. Until 1929 he was busy reproducing maps, his best work perhaps being the preparation of the *Century Atlas* for the Century Company of New York. The atlas was begun in 1895 and completed three years later; it was highly commended by geographic societies and explorers. He also made maps for various railroad companies and for school geographies, such as the one written by Tarr and McMurray. For reproducing maps he used wax engraving and copper electroplating.[18]

III

It has already been made clear that the railroads — especially the so-called transcontinental lines — attracted large numbers of foreign engineers. Among the earliest Norwegians to engage in railroad work was a Trondhjem graduate, Jesse Didrichsen Koren. Koren, after his arrival in 1877, tried his hand at several tasks, including the development of a North Dakota homestead. In 1882 he became an engineer with the Soo Line, in charge of construction near Sault Ste. Marie. Later transferring to the Northern Pacific, he was shortly made responsible for all track, bridge, and building designs — a job that later required the services of three men. In 1907 Koren was promoted to district engineer with headquarters at Spokane; his district was from Paradise, Montana, to Ellensburg, Washington, and it included

[17] *Normands-forbundets tidsskrift,* 45 (February, 1927); *Normands-forbundet,* 8:27–35, 82–94 (January and February, 1915).

[18] Alstad, *Trondhjemsteknikernes matrikel,* 37; information in Chicago archives of Norwegian-American Technical Society.

many branch lines in the wheat and fruit areas of Idaho and Washington. For nineteen years he was in full charge of all engineering work in this territory. Koren was considered typical of the old-school engineer who migrated in the seventies and eighties—polished, courteous, kindly, competent.[19]

Martinius Stixrud, a graduate of the Chalmers Institute at Gothenburg and of the Aachen Polytechnicum, spent his first summer in America, in 1881, with the Manitoba Railways. He switched to the bridge department of the Chicago, Milwaukee, and St. Paul Railway at Minneapolis in the fall of the same year. In 1883 he transferred to the Northern Pacific and was sent to the Pacific coast by this railroad. His experiences included the design of a switchback over Stampede Pass, a period with the Oregon Pacific Railroad, and the running of lines across the Cascade Mountains through Snoqualmie Pass for the Seattle, Lake Shore, and Eastern Railway. He designed and constructed the bridges of the latter railroad over the Spokane River. In 1890 he became city engineer of Seattle.[20]

The career of Hans Helland follows a similar pattern. Educated at the Polytechnicum in Dresden, he emigrated in 1881 and set his course for Texas, where railroad lines were desperately needed. Helland first served as construction engineer for the Texas Central Railroad; in 1889 he became vice-president and general manager of the Central Texas and Northwestern and of the Fort Worth and New Orleans Railroad companies. When these lines consolidated with the Houston and Texas Central Railroad in 1902, he became maintenance-of-way engineer for the entire system. Resigning in 1906, he located and constructed the Panhandle Short Line. Two years later he transferred to the San Antonio and Aransas Pass Railroad as maintenance-of-way engineer, remaining at this post until 1913, when he became city engineer of San Antonio.[21]

[19] Alstad, *Trondhjemsteknikernes matrikel,* 341; Alstad, *Tillegg,* 103; *Norwegian-American Technical Journal,* vol. 9, no. 1, p. 5 (June, 1936).

[20] American Society of Civil Engineers, *Transactions,* 51:463–465 (1903).

[21] American Society of Civil Engineers, *Transactions,* 93:1824 (1929); *Norwegian-American Technical Journal,* vol. 1, no. 2, p. 3 (May, 1928).

The outstanding railroad pioneer in the East and for some time the "grand old man" of the Norwegian engineers was Søren Munch Kielland, chief engineer of the Buffalo Creek Railroad. Kielland, a graduate of the Chalmers Institute, arrived in this country in 1881 and was employed by the Erie Railroad. His experiences in the fifty years that followed, which he later recorded in some detail, cover many of the tasks that faced an engineer in the epic period of American railroad construction. Engaged in improving and reconstructing the western division of the Erie Railroad, Kielland also took part in double-tracking and generally rebuilding the Buffalo Creek Railroad, designing bridges, yards, and buildings. He helped construct the protection along the lake shore for the Buffalo line and prepared records and maps.

When Robert Harris, a vice-president of the Erie Railroad, became president of the Northern Pacific, Kielland took employment with this line and moved to the west coast in 1885. He was requested to examine coal mines and start new towns along the Northern Pacific, chiefly in Washington. When Montana began to develop its railroad branches near Butte and Helena, Kielland was transferred to that state, becoming principal assistant to his former superior in the East. The two men built several branch lines with tunnels and high trestles, Kielland being in charge of all field and construction work. The undertaking was completed in 1888, and Kielland, seeking rest, made a trip to the homeland.

Upon his return to the United States, he accepted a position with the Lehigh Valley Railroad. His new work had to do with meeting the terminal requirements in and near Buffalo, the key link in the Great Lakes and eastern railroad transportation. He built warehouses and docks at Buffalo, Chicago, and West Superior. Kielland was forced out of this company following a shakeup in management. He then went out to Montana again for the Montana Railroad Company to assist in the development of new lines there. Put in charge of construction, Kielland located several hundred miles and started construc-

tion of the Montana Southern and Montana Midland lines, but the panic of 1893 and the depression that followed brought a halt to this work.

Kielland returned to Buffalo in 1896 and accepted a position with the Buffalo Creek Railroad, remaining with this company, for a long period as chief engineer, until his retirement in the early 1930's. He had realized early that this line held the key to vital expansions in and around Buffalo and he felt that it should be the great belt line of the Buffalo-Niagara territory. In the period 1897–1910, when E. F. Knibloe was general agent of the railroad, Kielland co-operated with him in developing numerous projects in which the line was interested. The Stony Point and Terminal Junction Railroad, which later became the South Buffalo Railroad, was organized by Kielland and Stephen T. Lockwood. The two men held the charter to the land that was later utilized by the Lackawanna Steel Company, the South Buffalo Railroad, and the Bethlehem Steel Company. Kielland, together with powerful associates, initiated the formation of the Niagara Transfer Railroad Company, which later became the property of the New York Central system. The establishments of the Wickwire, Dunlop, and General Electric companies and other industries now occupy territory made available by his efforts. The Buffalo River Extension survey was made by Kielland and C. Morse of the Erie line, the Buffalo Creek Railroad acquiring some of the most desirable right-of-way land. Thus, in the development of one of America's most vital transportation and industrial centers this engineer played a leading and deeply significant role. He also served as Norwegian consul in Buffalo.[22]

Carl J. Printz, a graduate of Horten's Technical School, has devoted the major part of his career in the New World to mechanical engineering with large industrial firms, but for a time after 1906 he was superintendent of construction for the

[22] See *Norden* (Chicago), 2:12 (November, 1930) and 3:2–4, 23 (July, 1931); *Norwegian-American Technical Journal,* vol. 1, no. 1, p. 3 (February, 1928); a record prepared by Kielland and made available to the present writer by Kielland's son, Rolf; and innumerable articles in the Norwegian-American press.

Milwaukee Electric Railway and Light Company. Moving to Toronto, he became Norwegian vice-consul and assumed a leading role in Norwegian-American activities there.[23]

Olaf Ridley Pihl, son of a distinguished railroad engineer in Norway, attended the Chalmers Institute in Sweden, worked for a time on the Norwegian railroads, and left for Toronto in 1880, together with two classmates, A. L. Hertzberg, later a division engineer of the Canadian Pacific, and S. M. Kielland. Pihl moved from Toronto to Portland, Oregon, where he was employed by the Oregon Railway and Navigation Company as topographer and resident engineer on construction. Later he was bridge engineer for another west coast firm and in 1887 he took employment with the federal government as assistant engineer in charge of constructing a canal and locks on the Columbia River. He planned a boat-railway scheme that overcame obstructions in the river between the Dalles and Celilo Falls. Pihl was afterwards engaged by the federal government at Buffalo and put in charge of reconstructing a part of the breakwater there. In 1900, together with Edward J. Hingston, he built the cofferdam, piers, foundation, and abutment for a movable dam and guide cribs and erected Chanoine wickets at Herr Island Lock and Dam in the Allegheny River, under the direction of the United States Engineer Office at Pittsburgh. In subsequent years Pihl completed numerous construction jobs for the Pittsburgh and Lake Erie Railroad, and the Youngwood, Pittsburgh, and Allegheny divisions of the Pennsylvania Railroad. In 1906 he formed a partnership with W. B. Miller; as contracting engineers they completed some 300 contracts for railroads and steel plants before Pihl's death in 1915.[24]

A complete list of the Norwegian engineers who devoted their best years to developing American railroads would be a long one indeed, but a few additional names must be mentioned. One of the most important on the Pacific coast was Olaf Winningstad, trained at Zurich and Aachen, who, follow-

[23] *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 144; *Nordmands-forbundet,* 21:202 (1928).

[24] American Society of Civil Engineers, *Transactions,* 80:2195–2198 (1916).

ing his arrival in California in 1880, served for a long time with the Southern Pacific.[25] Joachim Sundland, who also came in 1880, was chief engineer for the California Southern and later worked with the Union Pacific Railroad.[26] Lauritz N. Jenssen, like Sundland a graduate of the Trondhjem college, pioneered in Canadian railroad construction — both in the East and West — during the early years of the present century; he became district engineer with the Canadian Northern Ontario Railway.[27] O. J. Oien, who was educated at Christiania's Technical College, did noteworthy field work for the Northern Pacific Railway in North Dakota and Montana. Anton Wetlesen, a Bergen graduate employed since 1909 by the New York Central, is said to know every nail in his company's system. Frequently as many as ten or twelve Norwegians have been employed with him in the New York offices. Einar Weidemann, from the Trondhjem college, was designing engineer with the Pennsylvania Railroad and later structural engineer for the Chicago Union Station Company.[28] E. M. Tandberg, a Christiania graduate, has served with the Northern Pacific since 1909 and performed varied tasks for his line in the West. A Trondhjem man, R. A. Tanner, was assistant engineer in St. Paul of the water department of the same company.[29] Hugo Kolstad from Christiania, who has been with the Great Northern Railway in St. Paul since 1907, has specialized of late in bridge jobs. The same is true of C. F. Berg, a Trondhjem graduate, who is with the Chicago and North Western at Chicago. W. A. Grøndahl was for a time chief engineer of the Southern Pacific Railway; Haakon Christian Hauge was chief engineer of the Montana Midland Railroad, later holding a similar position in the East; and T. D. B. Grøner has held almost every position, including that of chief engineer, on several American lines.[30]

[25] *Nordmands-forbundet,* 20:128 (1927).
[26] Alstad, *Trondhjemsteknikernes matrikel,* 14.
[27] Alstad, *Trondhjemsteknikernes matrikel,* 80.
[28] Alstad, *Trondhjemsteknikernes matrikel,* 133.
[29] *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 22 (November, 1935).
[30] Alstad, *Trondhjemsteknikernes matrikel,* 198; Alstad, *Tillegg,* 56.

IV

Engineering extends beyond the problem of normal railroading. It includes, for example, the work of evaluation, a new field in which several Norwegian engineers have been largely engaged. Jakob Krogsti, whose preliminary technical education was received at Christiania, was inventory engineer and assistant engineer in the valuation department of the Northern Pacific at St. Paul until his death in 1926.[31] Haakon Falk, a graduate of Trondhjem's Technical College, also of St. Paul, is assistant valuation engineer with the same railroad at the present time. Others have contributed in the manufacturing field; the self-trained Johan M. Andersen, for example, as president of the Andersen Manufacturing Company in Boston, pioneered in the production of overhead line material and molded insulation for street railways. Andersen personally designed much of the present-day standard equipment in this field, his most notable work being the design and construction of switches, switchboards, circuit breakers, and similar products, together with purely mechanical devices, many of which he patented.[32] Frits Deinboll was chief bridge inspector for a portion of the New York Central Railroad. Erling Øyen, from Christiania, in the middle 1920's aroused considerable interest at Detroit with a patented plan for a wholly new elevated railway system with a single track.[33] Jens G. Schreuder, a graduate of Horten and Gothenburg, who was chief engineer and a vice-president of the Union Switch and Signal Company at Pittsburgh, worked out no less than 37 patented inventions in connection with railroad signal systems; much of this was done in co-operation with George Westinghouse. The electro-pneumatic signal apparatus now extensively used was the culmination of Schreuder's long study and application, and the fact that only slight changes in it have been made since his retirement in 1915 is a measure of his skill and efficiency.[34]

[31] *Norwegian-American Technical Journal*, vol. 5, no. 1, p. 10 (January, 1932).
[32] American Society of Mechanical Engineers, *Record and Index*, 2:347 (1928).
[33] Wong, *Norske utvandrere*, 165.
[34] Wong, *Norske utvandrere*, 158.

The technical career of one of the best-known Norwegian engineers in America, Frederic Schaefer, is bound up with the development of brake equipment for railway cars. Schaefer studied at the evening technical school in his native city of Stavanger. After being employed as chief draftsman in the Andersen Manufacturing Company at Boston, he arrived in Pittsburgh in 1902. Meeting a fellow Stavangeren, Gustav Benson, who was then chief engineer with the Westinghouse Electric Company, Schaefer took employment in this firm and remained there — spending one year in the French affiliate — until 1907, when he became mechanical engineer for the Summer Steel Car Company. In 1914 he established his own firm, the Schaefer Equipment Company, to manufacture brake equipment that he had invented. Like Ruud, he was successful in the business field, and his equipment is now universally installed on locomotives and passenger and freight cars. Patents cover at least 11 of his inventions, all of which were developed commercially by his company.[35]

Railroad rolling stock owes much of its development to Norwegian engineers, and of them none more nearly approaches the stature of Henrik V. von Zernikow Loss than Andrew Christianson. Like Loss, Christianson was a graduate of Horten's Technical School.

Christianson supplemented his Norwegian education with two years at Dresden and came to America in 1893. In Germany Christianson had prepared himself to become an engineer in the paper industry; his experiences in America, however, caused him to devote his career to the development of rolling stock. After shifting several times, he became draftsman in 1900 with the Pressed Steel Car Company at Pittsburgh. Four months later, when the Standard Steel Car Company of Butler, Pennsylvania, was organized, he became their chief draftsman. A year later he was shop engineer. In 1902 he was given the additional title of chief engineer in charge of the design of equipment and of estimating material costs, preparing specifi-

[35] *Stavanger aftenblad*, May 16, 1930; Wong, *Norske utvandrere*, 160.

cations, and assembling complete data for the sales department. As Christianson himself expressed it, the years after 1902 constituted a "strenuous time, as we lived then in the period of transition from wood cars to all-steel cars, which involved a tremendous amount of designing." He designed the first all-steel passenger car about 1905 or 1906, and had it ready for the International Congress at Washington. Christianson remained in this job until 1930, when the Standard Steel Car Company was absorbed by the Pullman Company.

During the twenty-eight years that Christianson served in the key engineering position for the Standard Steel Car Company, he also headed up a great deal of other work. He was in charge of the construction of the freight and passenger car plant at Hammond, Indiana, which was started in 1907. When the United States entered the First World War, he supervised the design of all the railroad cars used by the American army in France. Late in 1917 he was put in charge of the engineering and construction of about a thousand 9½-inch gun carriages, of the caterpillar type, with spare parts. For this job he had to enlarge the plant buildings of the Hammond passenger car department and also make a great many special tools. He was fortunate in having as an assistant L. H. Vold, a Horten classmate, who was considered the foremost tool designer of his day and had been in the employ of William Sellers for twenty-eight years. Vold was immediately responsible for the design and installation of the special machinery for manufacturing the gun carriages.[36] Because of the excellence of Vold's tools, his firm was able easily to outstrip its competitors. Rudolf Hammerstrom, a Horten graduate of 1903, was assistant chief engineer of ordnance and served as superintendent of manufacturing.[37]

[36] Vold was later first chief engineer of the research bureau and first chief engineer of plant with the Standard Steel Car Company at Butler. He holds a great number of patents, chiefly for drills, punches, and the like, some with Rudolf Hammerstrom and some with William Sellers.

[37] Hammerstrom studied the manufacture of heavy artillery in France on the invitation of the war department. Returning to the United States, he was named general superintendent in the production of 240-mm. howitzers, of which 10 were

In the postwar period Christianson continued to contribute to the evolution of the all-steel car. In 1927 he was sent to France to build a plant at La Rochelle which constructed sleeping and dining cars for Wagons-Lits. After completing about 180 cars, he was asked to design an all-steel sleeping and dining car; 120 cars of this design were built. As a result of careful planning, Christianson and his associates were able to reduce car weight some 6,000 kilograms below the old figure. When the Standard Steel Car Company was absorbed by Pullman, Christianson was assigned to special work, but in 1935 he became chief engineer and was assigned to the Pullman Car Works, Chicago. During the next five years he developed streamlined passenger trains and the new lightweight Pullman cars. In 1940, at his own request, he was appointed to the less strenuous position of consulting engineer for the Pullman-Standard Car Manufacturing Company. He died in 1942.

It is difficult to single out particular contributions made by Christianson. His United States patents alone total 88 and they cover almost every detail of car construction. He also designed and built a forge plant and took charge of experiments in making forged-steel car wheels. This business was later sold to the American Rolling Mill Company. But he will be remembered first and last for designing and building the first all-steel railway passenger car in the United States.[38]

M. A. Lagreid, a graduate of Bergen's Technical College, participated in the construction of the first all-welded streamlined train and supervised the installation of the air-conditioning equipment on the first air-conditioned cars of the Chicago, Milwaukee, and St. Paul Railroad. Still other engineers were identified in one way or another with the development of roll-

to be produced daily. He later continued to hold responsible engineering positions with Standard Steel Car and the United States Steel Corporation. Wong, *Norske utvandrere,* 161.

[38] Almost nothing has appeared in print about Christianson, who was excessively modest and retiring. The writeup about him in *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 178, suggests none of the greatness of his work, and even the *Chicago Tribune* account (July 3, 1942) that followed his death is extremely brief. The record given above is the result of strenuous efforts by the writer to get information directly from Christianson before his death.

ing stock. Sigvald Udstad from Trondhjem was for many years chief engineer with a large plant in St. Charles, Missouri, that produced railroad cars. Carl Allme of Horten was chief draftsman with the Standard Steel Car Company, where Finn Oyen, a graduate of Porsgrund, also served as car designer. Carl H. Knudsen invented in 1925 a successful new 1,000-horsepower locomotive of the Diesel type for the Baldwin Locomotive Works, where he was consultant; it was put into immediate use for both passenger and freight service on the Reading Railroad.[39] Theodore M. Kirkby, self-taught superintendent of motive power and equipment for the Green Bay and Western Railroad Company, was associated in earlier years with the construction of locomotives and freight and passenger cars used extensively on the Milwaukee Road and the Missouri, Kansas, and Texas line.

A significant contribution in the East was that of Olaf Garstad, assistant engineer for the New York Central Railroad. During the first quarter of the present century this Bergen graduate had a vital part in the construction of the Grand Central Terminal in the heart of New York City. Garstad was assistant engineer of the division for masonry and foundation work for track and building structures. One of the novel engineering problems met in this job was that of providing complete insulation of building foundations — which were carried down from the street through two track levels — in order to prevent the vibration and noise of train operation and street traffic from entering near-by buildings, hotels, and apartment houses. Construction of the terminal included the erection of independent structures in twenty-five city blocks, over two levels of tracks, and created no little interest in engineering circles.[40]

The discussion of railroads is incomplete without reference to J. O. Batzer, a Horten graduate who is technical superin-

[39] *Nordmands-forbundet,* 18:507 (1925).
[40] Information in the Chicago archives of the Norwegian-American Technical Society.

tendent of the Chicago Union Station Company. Batzer was earlier chief engineer in the construction of the Burlington skyscraper on Jackson Boulevard. His present position, which he has held since 1922, involves directing the small army of engineers, electricians, and mechanics who are responsible for the perfect operation of the complex system of the Chicago Union Station. This, unquestionably, is the hub of passenger transportation in the United States.[41]

V

It was inevitable, in the light of the expanding function of government, that many engineers should find their way into municipal, state, and federal employment. Such men as Berle and Aus, Pihlfeldt and Cappelen, Illstrup and Singstad were government employees. There are, in addition, several Norwegian engineers who, while making undeniable contributions in specialized technical fields, may be considered primarily municipal employees.

One of the first was G. L. Clausen, a graduate of Trondhjem, who served as an assistant engineer in the building of Pullman, a suburb of Chicago, in 1880–81. Later assistant engineer for the federal government on the Hennepin Canal Survey, Clausen became, in 1883, village engineer of Hyde Park, a territory 48 miles square at the northern tip of Chicago, now a part of the city. He held this position until 1888, when he opened an engineering office in Chicago. Although his was a private practice, he made a specialty of municipal work, designing and supervising the construction of sewer systems and waterworks in many cities and villages, among them Blue Island, Elmhurst, and other Chicago suburbs. For several years he was superintendent of the Chicago sewer department, establishing an enviable reputation in this field. His firm also specialized in land surveying and did the field engineering for a majority of the city's large skyscrapers. Clausen was recognized as a sound authority on "loop surveying," and it is interesting to note

[41] *Skandinaven,* April 26, 1935; Wong, *Norske utvandrere,* 203.

that he took part in the construction of a number of the buildings at both the Columbian and Century of Progress expositions. Finally, he figured in the planning of Chicago's elaborate underground freight tunnel system.[42]

Martinius Stixrud became city engineer of Seattle in 1890. He apparently "did not give satisfaction to the politicians, who were unable to use him and his office as they pleased. He was most shamefully treated, and although ousted from office, was completely exonerated, and came through this blackmailing process victorious." Before this unpleasant experience, he had worked with J. E. Ericson (later city engineer in Chicago) in preparing plans for the water and sewage systems in Seattle. After his ouster, Stixrud practiced as a consulting engineer in partnership with a C. Næsten. He carried on the most diverse kind of engineering. During the winter of 1892–93 he was in California and Mexico with a plan for irrigating 600,000 acres of desert land in the Colorado River basin. His proposed intake was on the river at Hanlon's Ferry, near Yuma. The business side of the project failed and Stixrud returned to the state of Washington, where he became engineer for the board of tideland appraisers in King County.

[He made] a very extensive survey of Seattle and Ballard Harbors, establishing harbor lines and waterways, and plotted the tideland areas at Seattle, Ballard and part of Tacoma Harbors. Especially for Seattle this was a work of great importance, as it dealt with the future plans of Seattle Harbor, railway terminals and manufacturing districts. Mr. Stixrud did not succeed in getting his general plan of the main part of Seattle Harbor accepted. Captain T. W. Symons . . . representing strong interests, had a revised plan, which was accepted. Mr. Stixrud's plan was one with tidal basins, the rise of the tide being 16 ft. Captain Symons' plan was for open waterways, which appeared to suit the immediate or near future.

A note of frustration runs through the brilliant career of young Stixrud, which is climaxed by his premature death in 1901.[43]

[42] Alstad, *Trondhjemsteknikernes matrikel,* 21; *Norwegian-American Technical Journal,* vol. 3, no. 1, p. 15 (February, 1930), and vol. 11, no. 1, p. 13 (February, 1938); *Skandinaven,* April 16, 1937; and *Scandia,* April 7, 1938.

[43] S. T. M. B. Kielland, in American Society of Civil Engineers, *Transactions,* 51:463–465 (1903).

In Texas, Hans Helland supplemented his pioneer railroad work by serving as city engineer of San Antonio from 1913 to 1921, during the city's "first struggle" toward municipal improvement. "It is noteworthy," we read, "that, after approximately thirty-two years of active building and improvement of railroads in Texas, Mr. Helland should then take up the work of enlarging a pioneer city to one of metropolitan proportions."[44] After 1921 Helland engaged in private practice at San Antonio.[45]

The most colorful municipal figure is Anton L. Pettersen, a graduate of Bergen's Technical College. Following a brief period with the Lehigh Valley Railroad, Pettersen went to Passaic, New Jersey, in 1889. Interested in politics, he became a member of the state legislature, started an engineering firm of his own, and later became director of the city's communications. He has also served in many another municipal capacity —in the sanitary division, on the board of freeholders, and, for five years, as city engineer.[46]

Of the younger men, one of the most promising is Erling A. Normann, engineer-examiner in Chicago for the federal government. A graduate of Trondhjem's Technical College, he came to America in the twenties and was put in charge of engineering in office and field for the Blue Bell Construction Company. In 1935 he became designing engineer with the sanitary district of Chicago during the construction of its $70,000,000 improvement project, which included the largest sewage treatment plant in the world. Later he was put in charge of the structural design of the major sections of the Chicago River Controlling Works. Since 1938 he has been employed by the United States government.[47]

In villages, towns, and counties the country over, Norwegian engineers have served in one official capacity or another,

[44] American Society of Civil Engineers, *Transactions*, 93:1824 (1929).

[45] Alstad, *Trondhjemsteknikernes matrikel*, 6; *Norwegian-American Technical Journal*, vol. 1, no. 2, p. 3 (May, 1928).

[46] *Minneapolis tidende*, October 3, 1922; *Nordisk tidende*, September 25, 1924.

[47] *Norwegian-American Technical Journal*, vol. 11, no. 1, p. 9 (February, 1938).

and practically every city of importance has employed others in positions both large and small. Chicago and Minneapolis have drawn most heavily on the supply of available men.[48] There have been times when the conversation in the Minneapolis city drafting rooms has been an effortless Norwegian. Representative of the city engineer group is a Trondhjem man, John Stedje, structural engineer in the Chicago department of public works, who had a significant part in the building of the vast Union Station of that city, of Wacker Drive, and of at least a half-dozen bascule bridges. In the West, O. S. Willumsen, of Seattle, is a good example of the state employee; in 1930 he made an early report for the federal government on the Grand Coulee Dam project; he has also been employed in the national forest service. Willumsen is a graduate of Christiania's Technical College.

VI

The young engineer always carried the hope of becoming chief engineer; and despite the tendency of some owners to favor native Americans for this position, a surprising number of immigrants achieved their goal. Apart from the chief engineer's importance in the technical life of this country, he was also — as we have indicated — a pole of attraction in the immigration story. If he chanced to be Norwegian, it was certain that he would draw young countrymen by the dozen.

Gustav Benson, who like Schaefer worked in the Stavanger shipyards and attended the local evening technical school, came to Pittsburgh in the early 1890's. He became associated with the Westinghouse Electric Company, and in the hard years after 1893 was a friendly counselor to graduates of the schools of his homeland, employing a considerable number of them.[49] Though few have enjoyed Benson's popularity, many have held similar posts. Otto Julius Andreason, who was responsible for projects in Canada, Mexico, and Cuba, as well

[48] See, for example, Carl G. O. Hansen, in *Skandinaven*, September 11, 1936; this article is one of a series entitled "Tvillingbyernes norske saga."

[49] *Stavanger aftenblad*, September 28, 1929.

as in the United States, was recently chief engineer for the famous New York firm of William Barclay Parsons.[50] Axel Wallem, a graduate of Bergen's Technical College, for a time made his living by playing the piano. He became chief engineer and superintendent of the Harrison Safety Boiler Works of Philadelphia, now the Cochrane Corporation. He was also secretary, vice-president, and general works manager of this company, which specializes in steam power-plant products; his many executive duties did not prevent him from inventing a number of items, among them the famous Cochrane multiport relief valve.[51]

In Chicago, I. H. Faleide, who was also educated at Bergen, is now vice-president of the McKenzie-Hauge Company. He was chief engineer of the Folwell Engineering Company for twenty-four years and thus had charge of designing and supervising the construction of grain elevators, flour and feed mills, industrial plants, concrete bridges, and the like.[52] Thomas Pettersen, an 1896 graduate of Christiania, was a popular chief engineer for the Peabody Coal Company. For a time he operated an automobile company of his own, and before his death he became chief engineer for the MacDonald Engineering Company, in the last capacity supervising the construction of cement plants in Moscow, Russia.[53] A Trondhjem graduate, Ludwig Skog, was vice-president and chief engineer for Sargent and Lundy, Inc., before becoming a partner in this large and significant firm.[54]

About the country Norwegian engineers have held and still hold leading positions in an amazing number of industries and technical undertakings. Sverre Trumpy, trained at Berlin, was in charge of the engineering department and drafting room of the Gisholt Machine Company of Madison, Wisconsin.[55] Hans

[50] *Skandinaven,* December 10, 1926.

[51] *Norwegian-American Technical Journal,* vol. 10, no. 1, p. 6 (February, 1937).

[52] Wong, *Norske utvandrere,* 204; *Norwegian-American Technical Journal,* vol. 1, no. 3, p. 5 (September, 1928).

[53] *Skandinaven,* October 19, 1934; *Scandia,* October 18, 1934; and *Norwegian-American Technical Journal,* vol. 10, no. 1, p. 5 (February, 1937).

[54] *Norwegian-American Technical Journal,* vol. 5, no. 1, p. 10 (January, 1932).

[55] American Society of Mechanical Engineers, *Transactions,* 39:1, 241 (1917).

Nickolias Halversen was mechanical head of the Kimble Glass Company, Vineland, New Jersey, and before 1910 had a varied career in the type and automobile industries.[56] Sverre Lund, from Trondhjem, was chief engineer of the Eastern Bridge and Structural Company of Worcester, Massachusetts. Finn Mathiesen, who studied at Horten and Christiania, held a similar position for a time with the great architect, D. H. Burnham of Chicago. John Mosby, a Trondhjem graduate, was head of the mechanical engineering department and superintendent of the gas compressing station and the gasoline absorption plants of the People's National Gas Company, the Reserve Gas Company, and the Hope Natural Gas Company in West Virginia, Pennsylvania, and Ohio.

At Detroit Carl J. Oxford, who received his technical education at the University of Michigan, is chief engineer of the National Twist Drill and Tool Company and author of many inventions in metal-cutting tools; Einar Almdale is factory manager of the Midland Steel Products Company, and was the inventor, among other things, of a commonly used welded nut. Alf Jørgen Strømsted, a graduate of Norway's Institute of Technology and co-engineer for the electrical design of the Wards Island sewage treatment works for New York City, is chief electrical engineer with George G. Sharp of the same city. Sigurd Neatwait, who was also trained at Norway's Institute, is chief engineer of the Republic Fireproofing Company in New York. Oscar Wilhelm Lilliedahl, representing Porsgrund, holds the same position with the Logan Engineering Company in Chicago. Einar A. Johnson was chief mechanical engineer for the American Gas and Electric Company. Carl Stenbol, inventor of a wind alarm for the protection of ore and coal bridges, is chief engineer of the Algoma Steel Corporation at Sault Ste. Marie, while Otto Holm Anderson holds a similar position with the National Steel Car Corporation, Limited, of Hamilton, Ontario. And O. J. Skawden, a graduate of the Insti-

[56] American Society of Mechanical Engineers, *Transactions*, vol. 56, record and index, p. 20 (1934).

tute, is chief engineer of the Sutton Engineering Company of Bellefonte, Pennsylvania.

The most casual reading of the publications of the Norwegian technical schools is sufficient to demonstrate how incomplete is the list given above. We find that Johannes Fredrik Devold (Trondhjem) was chief engineer with the Williams Engine Works and the Webster Manufacturing Company of Chicago; Berthel Michael Krohn (Bergen) with the Phoenix Bridge Company of Phoenixville, Pennsylvania; Ole Oftedal (Horten) with the American Shipbuilding Company of Buffalo; Matheus Iversen Funder (Trondhjem) with the Diamond Alkali Company of Painesville, Ohio; Reinhardt Daae (Bergen) with the Marchall Foundry Company at Pittsburgh; Einar Martin Arentzen (Trondhjem) with the Joy Manufacturing Company of Franklin, Pennsylvania; Thomas Edward Kulø (Trondhjem) with the Lion Manufacturing Company of Chicago; and Finn Berger Hudson (Trondhjem) with the Chent Motor Company of Ottawa, Illinois. Our task, happily, is not to exhaust the list but merely to illustrate the extent to which the immigrant engineers of Norway's schools climbed to the top engineering positions in an infinite variety of American industries and thus figured both in the flow of immigration and in the technical story of production.

VII

It is frequently but a short step from the practice of engineering to the operation of a business. The Norwegian engineers as a group, however, have proved to be far less able as businessmen than as technicians, despite several outstanding exceptions of the Tinius Olsen, Edwin Ruud, and Frederic Schaefer type. The reader will have observed that many of the men under consideration in this volume quit engineering positions to exploit inventions or otherwise to assume the risks of business. Most of them later returned to resume former or similar engineering positions. Some of the exceptions will be discussed here.

Most of the modern buildings in New York and in other

cities are supplied with brass fire-extinguishing equipment produced by Albert E. Hansen, president of the Elkhart Brass Manufacturing Company of Elkhart, Indiana. Hansen's patented fire department nozzles will be found in Radio City, the Minneapolis Foshay Tower and the Auditorium, the St. Paul post office, and 27 of the new federal buildings in Washington, D. C., to mention only a few modern structures. Hansen, a graduate of the Christiania Technical Evening School, came to the United States in 1889, and continued his studies at a Chicago evening school. For a while he served as foreman of a bicycle firm. In 1901 he founded his present company.[57]

A most interesting firm is an airbrush company established by Jens A. Paasche of Chicago. Paasche received his first technical training under a Trondhjem gunmaker and then worked in the Kongsberg gun factory. Coming to Chicago in 1900, he was soon part owner of the Wold Airbrush Company. Realizing that he had found the line that interested him most, Paasche in 1904 sold his interests in the Wold firm and founded the Paasche Brothers Airbrush Company, together with a brother who left the firm shortly after the business was started. The company at first repaired old brushes — and business was good. Paasche watched his plant grow until about 140 persons were employed and he had some 40 branches and offices in the United States and Canada. His clients were everywhere. Paasche's many inventions, about 60 of which are patented, are incorporated in the airbrushes, the most modern of their kind, that he now produces in great quantities. The brush holder looks like a revolver; various types of brushes may be inserted into it. The airbrush is used to paint automobiles, airplanes, houses, bridges, machines, china, furniture, cheap industrial products, and the steel skeletons of skyscrapers. It is claimed that a painter can do an ordinary week's work in two days with one of the airbrushes.

The full importance of the airbrush, in the development of which Paasche has had a major part, has been emphasized in

[57] *Skandinaven*, February 1, 1935.

the *Journal* of the Norwegian-American Technical Society. For example, the brush is so accurately controlled that in art work the veins in the human eyeball, even on a miniature portrait, can be easily reproduced. The brush also makes possible realistic freehand air drawings; exceptionally fine detail and delicate light and shadow effects result. In general, according to the *Journal*, the most accurate reproduction of art works requires air to give life to the copy, some authorities even arguing that the masterpieces of the future must be "air processed" if they are to be realistically reproduced.[58]

Paasche had to develop many airbrushes before his present universal convertible, multi-head brush was perfected. It can be used with any material, from the lightest paints to asphalt and rubber cement; it will also paint anything from the finest line to a band 52 inches wide, and it operates on high or low pressure. Paasche's equipment is now standard for all finishing and coating operations in factories the world over. Surveys conducted among a hundred of the leading industrial concerns using his equipment show an average yearly saving of 77.83 per cent over previous painting methods. It was found that many decorative effects could be achieved with the airbrush —veiling, tinting, and stenciling, for example. In industry, the product to be coated may be placed on a turntable or a chain conveyor moving toward a coating station; here one, two, three, or even four colors may be applied at one time with perfect uniformity. The speed of the painting process is regulated only by the loading and unloading capacity of the conveyor operators. Paasche also developed portable machines for use by master painters, contractors, and decorators for air painting and coating houses, hospitals, and other buildings, both exterior and interior.[59]

When one considers the prominence of Norwegian chemical engineers in the cellulose field, it is not surprising to find a New York firm, G. D. Jenssen and Company, specializing in

[58] Volume 5, no. 1, p. 4, 11 (January, 1932).

[59] See also *Skandinaven*, November 22, 1935, and July 12, 1940; *Nordmandsforbundet*, 21:123 (1928); and Wong, *Norske utvandrere*, 211.

the production of reinforced concrete acid towers and the special machinery used in cellulose plants. Two Norwegian engineers, G. D. Jenssen and O. I. Berger, graduates respectively of Trondhjem and Christiania, co-operated in this project, which resulted in a wide manufacturing and consulting business.[60]

There are three Milwaukee factories that are unique in that they have no competitors; all of them have resulted from the initiative of a Norwegian engineer, Haakon T. Olsen. The first is the Arto Engineering Company, which turns out machines used in various industries, but chiefly in the production of automobiles and radios. His Pulp Reproduction Company makes cellulose articles, and the Counter and Control Company produces control machines used in all mass production. Olsen studied at Christiania and Karlsruhe.[61]

VIII

An engineer might, after having acquired a technical reputation, organize a consulting office; this was a common practice, especially among the earlier arrivals. Thus, though engaged in business, the engineer remains an engineer, having merely decided to strike out alone in hopes of attaining greater independence or increased financial gain. Men like Olaf Hoff, Henrik von Zernikow Loss, and other Norwegians did some of their best work in America while serving as consulting engineers. It is also true that many, perhaps most, returned to the greater security and the concentration on purely technical problems that go with working for others.

An outstanding example of a successful consulting engineer was Nathan T. Ronneberg of Chicago, a graduate of Bergen and Darmstadt. In 1901 Ronneberg and S. C. Anker Holth opened the engineering office of Holth and Ronneberg, which lasted only a short time before Holth was called away on special experimental work. Ronneberg next went into partnership with O. J. Westcott, who was formerly chief engineer for the

[60] Wong, *Norske utvandrere,* 75.
[61] Magnus Bjørndal, in *Nordmanns-forbundet,* 12:397 (1939).

Illinois Steel Company. During the nine years that they were together, they did the engineering work for more than 50 theaters, numerous office and factory buildings, hotels, and bridges. In 1910 Ronneberg sold his interest in the firm to Westcott and returned to Norway for a rest. One year later he was back in America, starting a new business with one of his former draftsmen, R. G. Pierce. They maintained offices in the Otis Building in Chicago for seventeen years, during which they planned and financed over 60 laundries and Ronneberg became one of the foremost authorities on modern laundry construction. When in 1928 Pierce left the company, Ronneberg took his son, Earl F., into the business and adopted the firm name of N. Ronneberg, Inc. From then until his death in 1939 he was active in planning and financing modern hotels, apartment hotels, and large apartment projects, as well as in straight industrial engineering work.[62]

Not infrequently engineers are enticed by the possibilities in the construction field and enter into contracting, where their technical knowledge naturally proves of inestimable value. Harold A. Boedtker, of Trondhjem's Technical College, for example, abandoned railroad engineering to become a railroad construction contractor; after 1890 he was a partner in the Heidenreich Company, which specialized in grain elevator construction. This company then branched out into general construction and built, among other things, two sections of the Chicago sanitary district drainage canal and the government locks on the Hennepin Canal, the last under Boedtker's direct supervision. In 1895 he organized H. A. Boedtker and Company and obtained several large railroad construction contracts, finishing this work in 1903. He then contracted with the state of New York to build a part of the revived Erie Canal; he had been engaged for further construction on the canal when he died in 1905.[63]

[62] *Norwegian-American Technical Journal,* vol. 3, no. 1, p. 5 (February, 1930); *Stavanger aftenblad,* February 1, 1930; *Festskrift ved Bergens tekniske skoles 25-aars jubilæum,* 60.

[63] *Norwegian-American Technical Journal,* vol. 2, no. 1, p. 15 (March, 1929); Alstad, *Trondhjemsteknikernes matrikel,* 43.

A leading Norwegian contractor who has an engineering background is J. A. Holmboe, retired, of Oklahoma City. Holmboe, following graduation from Christiania's Technical College, worked up from draftsman and, like so many others, did a great deal of estimating and drafting for a number of buildings at the Columbian Exposition in 1893. He was destined, however, to spend his best years in the South; he worked for the Louisville Bridge and Iron Company during a boom period and later branched out as a consulting engineer, undertaking building and bridge designs and carrying on a general engineering practice. While thus employed he became estimator in the field of construction for a large southern contracting firm. This contact, the discovery of his chief interest — contracting — and his financial ambitions shaped his later life. But before entering the contracting business independently, he served as vice-president and chief engineer for the Sneed Architectural Iron Company of Louisville and was employed as consulting engineer in the building of the first phosphate plant in Florida, made entirely of reinforced concrete. In the summer of 1909 he moved to Oklahoma City and thereafter engaged continuously in building construction, chiefly in Oklahoma and Texas. He executed about $15,000,000 in contracts and earned a reputation for quality workmanship and great integrity.[64]

Mention will be made of a few others who engaged as consulting engineers or building contractors. F. C. H. Arentz, of Trondhjem, was engineer and contractor for steel construction at Joliet, Illinois, from 1908 until shortly before his death in 1939.[65] Olaf Otto from Porsgrund and Strelitz, after serving in the drafting department of the Tennessee Coal and Iron Company, in 1911 went into business in Savannah as a civil engineer and general contractor. His most important work was the construction of the Savannah Bridge for the state highway departments of Georgia and South Carolina. The bridge

[64] *Norwegian-American Technical Journal*, vol. 5, no. 1, p. 6 (January, 1932).

[65] Alstad, *Trondhjemsteknikernes matrikel*, 35; materials in Chicago archives of Norwegian-American Technical Society.

is about five miles long and crosses three large rivers and several creeks.[66] Edward Mørch Fasting, a graduate of Bergen's Technical College, is the owner of the E. M. Fasting Construction Company of Chicago. On the west coast Peter H. Hostmark, a graduate of the Institute of Technology at Trondhjem, has been doing engineering work on a contract basis in Seattle since 1931; his projects include the North Beach sewage and drainage system of Seattle and the Howe Sound Ore Mill at Chelan, Washington. Before World War II Hostmark was one of the most vigorous promoters of the ski sport in the Seattle area, and during the war he was ground rescue officer of the American First Arctic Search and Rescue Squadron in Greenland.[67]

[66] Materials in Chicago archives of Norwegian-American Technical Society.
[67] *Washington posten,* June 23, 1944.

MACHINES: THEIR MAKERS AND MASTERS

THE careers of such men as Anker Holth, Edwin Ruud, Tinius Olsen, von Zernikow Loss, and Carl Barth give ample evidence that in the field of mechanical engineering the immigrant Norwegians made important contributions to modern life. When, as frequently happens, these men and their work are isolated from the larger group to which they belong, they are seen in false perspective; they were merely the conspicuous leaders of a small but constant stream of mechanical engineers who began their trek from the homeland in the 1860's and continued to arrive on American shores until very recently. It was natural that the graduates of Horten's Technical School should have been prominent—particularly in the nineteenth century—in the development of the mechanic arts and the machine, since they were the first of the Norwegian group to appear in this country; and their education, based as it was on theoretical fundamentals, equipped them peculiarly well for the many-sided developments that were a part of our national economic life. Their ranks, however, were soon swelled by men from Trondhjem, Christiania, Bergen, Porsgrund, and elsewhere—and by not a few who left Europe without benefit of a formal technical education.

I

In the mechanical engineers the dominant characteristic is inventiveness. In fact the interested student must discard, in this case, any rigid distinction between engineering and invention—as he must necessarily also erase the line that separates "pure" from "applied" science in the general story of engineering. The routine application of skills is the only contribution,

though a valuable one, of some engineers; but what is more frequently the case is that engineers of all types, while in the line of duty, are constantly inventing new processes, adding something to the work of their predecessors, and projecting new lines of investigation for those who follow. This is notable with the mechanical engineers, a fair number of whose contributions may properly be called inventions.

When discussing inventions and inventors, especially in a volume that focuses interest on personalities, it is well to keep several thoughts clearly in mind. The extremely individualistic interpretation of invention, once so common, must definitely be abandoned, for as one writer has expressed it, it "obscures the laws of interdependence between the inventive genius and economic society." When viewed in historical perspective, inventions are—in other words—as much the product as the cause of the machine age; it is the collective urge of technical and economic life far more than conscious motive that "furnishes the background and presupposition of their [*the inventors'*] activities" and forces the student to recognize a "duality of collective atmosphere and individual inspiration."[1] Furthermore, mechanical invention, which Americans tend to associate largely with their own continent, swept over western Europe and came to the New World with those who settled it. The American inventor, regardless of birth and training, is constantly drawing upon a technical heritage, and his work is rooted in principles that are distinctly European. Nor is there anything fundamental in American nature to make us more inventive than other peoples. Yet it is a fact that "the social and economic effect of invention is nowhere so apparent" as in the United States, and one searches in vain for "more daring experiments in engineering." In the words of Waldemar Kaempffert, "nowhere is the machine more in evidence; nowhere has the industrialization of old crafts been carried so far; and nowhere is the future state of mechanized society so clearly fore-

[1] Carl Brinkmann, "Invention," in *Encyclopaedia of the Social Sciences,* 8:247–249 (New York, 1932). By permission of the Macmillan Company, publishers.

shadowed. In the wilderness of what was destined to become the United States, with unlimited resources, the inventive genius of western European settlers, untrammeled by tradition, found free play."[2] Finally, directed invention—whether sponsored by private or public groups—has come to assume a dominant role in our technical life. Great laboratories, experimental stations, and the various departments of rationalized industry, in which many well-trained minds pool their ideas as well as the work of their skilled hands, are rapidly taking the place of gifted individuals; to a large extent they have already "exchanged the creative and individual for the cumulative and collective function,"[3] thus pulling the curtain on the heroic act of a pioneer age that is passing—and preparing for another great era.

II

What sets the immigrant engineer apart in the story of mechanical engineering is the fact that in him are combined the actual migration of the technical heritage and the training needed for cultivating the almost limitless potentialities of the American economic scene. The Norwegian engineers, who were in no sense unusual and were relatively late in arriving, contributed their full share of inventors. Some of them have already been discussed here; there are others who have received recognition only within limited technical circles.

One prominent inventor among the Norwegian engineers is a graduate and former instructor of Trondhjem's Technical College, O. G. Halvorsen, who now lives in Chicago. He became professor of mechanical and marine engineering at the school in 1908 after having studied advanced mathematics at the Sorbonne; he remained at this post until 1921, when he left with his family for America. At Trondhjem he had made an extensive study of ship propellers and had designed what is known as the Halvorsen propeller. While investigating the flow of water

[2] Kaempffert, "Invention as a Social Manifestation," in Charles A. Beard, ed., *A Century of Progress*, 22 (Chicago and New York, 1933).

[3] Brinkmann, in *Encyclopaedia of the Social Sciences*, 8:250. By permission of the Macmillan Company, publishers.

as it passes over an ordinary propeller blade, Halvorsen found that it spreads out radially, thereby reducing the diameter of the column of water against which the propeller thrusts. After making about 2,000 tests extending over a period of about seven years, he discovered the law for this radial movement of the water. The propeller that he designed eliminates the wastes created by ordinary blades. In Chicago Halvorsen established a business to manufacture a screw propeller which has been widely used as a brine circulator in ice plants and cooling and mixing devices. He is disappointed over the failure of shipbuilders to adopt his propeller in seagoing vessels.[4]

Few men have so many inventions credited to them as does H. O. Hem, consultant with the Toledo Scale Company. At the age of eight, he constructed an ingenious steam turbine and several steam engines of the slide-valve type. Two years later he was designing and building a sewing machine. Significantly, one of his many other boyhood products was a set of weighing scales. Hem arrived in the United States in 1882, and in 1889 he became engineer with the H. N. Strait Manufacturing Company of Kansas City, producers of weighing scales. Becoming chief engineer, superintendent, and vice-president, he designed a whole line of Monarch scales, cooperage machinery, hay baling presses, and many other devices. He later developed a line of Strait scales ranging in size from 16 by 24-inch platforms to railroad track scales with platforms 100 feet long. In 1915 he became consulting engineer with the Toledo Scale Company and in 1928 chief engineer. Again he designed a new line of scales, including heavy-capacity ones, and some special instruments required by the government in the First World War.

Since then he has designed scales to determine the center of gravity of connecting rods, such as are used in automobile and airplane engines, also for standardizing the weight of reciprocating parts making them interchangeable, and scales to determine the wearing qualities of automobile tires. He also has designed many types of special scales used in wind tunnels in aeronautical tests, and machines for determining the weight of commodities passing over

[4] Alstad, *Trondhjemsteknikernes matrikel*, 126; Alstad, *Tillegg*, 36; *Skandinaven*, November 7, 1932. Halvorsen also supplied additional information.

a conveyor belt, for integrating the power of extruding machines, for automatically weighing predetermined loads, for testing spring and water meters, for determining gas and air consumption in engines and turbines and for testing and automatically sorting compression springs such as are used in automobiles, valve springs, clutch springs, springs for knee action—and for automatically counterbalancing the tare of cars moving over scales. One of his most noteworthy inventions is the universal testing machine, in which the power is applied by hydraulic means and the reaction counterbalanced by levers and automatic pendulum indicating mechanism. One of the difficult scale problems which he solved was the automatic weighing of loaded cars hoisted out of a mine and containing varying proportions of slate and coal, the cars themselves being of different sizes and weights. The scale he designed weighs without an attendant and records the net amount of coal in each car regardless of the amount of slate, the factors being the cubic content of the cars and the specific gravity of coal and slate. At present (1938) he is manufacturing a scale that will determine the air pressure on large tunnels under construction in Russia.[5]

In 1932 Hem was awarded the John Price Wetherill medal by the Franklin Institute, "in consideration of the ingenuity shown in perfecting scales of the pendulum type, improving their accuracy, reliability, and sensitiveness, and the application of these scales to specific purposes."[6] Altogether Hem has taken out patents on more than 100 inventions, which include steam and gas engines, centrifugal pumps, cranes, and machine tools, as well as the items mentioned above.[7]

Hem's inventive genius was applied in the field of aviation during World War II. Most important of his contributions to the war effort was the design of all-important wind tunnel measuring systems in the United States. The chief device in these tunnels is a scale that accurately measures and records all the forces acting on a plane in flight. His equipment, furthermore, was used in icing, pressure, and altitude tunnels. His

[5] *National Cyclopædia of American Biography*, Current volume E, p. 487 (New York, 1938).

[6] *Toledo System*, vol. 26, no. 6, p. 2 (June, 1932). For other items about Hem's honors and awards, see *Toledo System*, vol. 30, no. 7, p. 2 (July, 1936); vol. 32, no. 1, p. 8 (January, 1938); vol. 32, no. 4, p. 3 (April, 1938).

[7] For more information, see *Minneapolis tidende*, September 14, 1927, and June 9, 1932; *Sønner af Norge*, 30:110 (April, 1933).

scales also made it possible to measure the torque of a plane's engine and its fuel and oil consumption. Almost all dynamometer installations in this country are the products of his skill. Hem also introduced devices to weigh planes, especially heavy bombers, and to determine the distribution of weight, as well as the center of gravity, in these craft.[8]

John Graw Rock, who received his early technical education at Trondhjem, organized John G. Rock and Company and later the Volute Spring Shock Absorber Company of New Rochelle and Mt. Vernon, New York, to manufacture his invention, the Rex automobile shock absorber. Because of financial reverses, he abandoned the business in 1915 and thereafter worked for other firms. In Norway he was author of a reference book for engineers and mechanics. His many inventions in America include safety doors for street and railroad cars, safety stop devices for railroad cars, a safety clutch for factory shaftings, automatic grease cups for loose pulleys, an internal combustion turbine, a non-explosive kerosene stove, a reversing timer for gasoline motors, the double volute spring, a thread and milling machine, a machine lap for taper holes, tool holders, a shutter for moving-picture machines, parts for electric batteries, gasoline and kerosene motors, timers, carburetors, wire-bending and spring-winding machines, and various tools.[9]

Thorvald Naglestad Garson's name broke into the news in 1917, at a time of labor shortages and high wages, in connection with an electric crane operated on an entirely original principle. Employing a single drum and one line, it did all the necessary hoisting and swinging and quickly proved itself in a munitions plant, where it was used to load ammunition onto railroad cars. Using this crane, one man was able to do the work that had required twelve.[10] Garson, a graduate of Horten's Technical School, has earned a reputation as a competent engineer.

Bjarne Schieldrop, a Bergen graduate, was associated with the American Window Glass Company and the Libby-Owens

[8] *Industrial Aviation,* vol. 3, no. 6, p. 30, 58 (December, 1945).
[9] American Society of Mechanical Engineers, *Record and Index,* 3: 354 (1929).
[10] *Nordisk tidende,* July 12, 1917; *Nordmands-forbundet,* 10: 444 (1917).

Sheet Glass Company as fuel engineer, and later served as director of the glass department in the Blaw-Knox Company of Pittsburgh. He has taken out many patents for bettering glass and steel ovens. One noteworthy invention is a so-called dolomite machine which is reputed to have solved a problem that beset the steel industry for some twenty years; it is now produced by Blaw-Knox.[11]

Sigurd Bøe saw the possibilities in slag as a building material, allied himself with a chemical engineer, Einar Christensen, and produced the bobrick stone. The usable coke in the slag is first removed and the residue is then mixed with cement and shaped into convenient building forms. Bøe's firm, the National Building Unit Corporation, with main office in Philadelphia, claimed that its bricks were fireproof and almost soundproof.[12]

The Hofgaard Remington Corporation was organized in the twenties to produce a calculating machine invented by Rolf Hofgaard. His machine, known as the "business brain," combined features of many other machines; a cash register, bookkeeper, and adding machine, it records a full account of every sale, with deductions, discounts, and the like, and gives a final total. Hofgaard's system, which was based on original mathematical research and is incorporated in his machine, was later taken over by the National Cash Register Company, which has not marketed the product. It is interesting to note that Rolf is the son of Elias Hofgaard, the Norwegian educator who constructed a machine on which the blind can write; Helen Keller was reputedly trained in the principles of the Hofgaard method.[13]

The announcement was made in 1933 that John Selvik had invented a machine that would produce fiber for the manufacture of sacking, thereby eliminating the need for imported material. Selvik, a Horten graduate, patented an economical method of turning hemp or flax into fiber.[14]

[11] *Nordisk tidende,* November 5, 1925.
[12] *Nordmands-forbundet,* 19:286 (1926); 22:244 (1929).
[13] *Nordmands-forbundet,* 22:201 (1929).
[14] *Minneapolis tidende,* February 16, 1933; *Nordmanns-forbundet,* 26:123 (1933).

Of great importance to the dairy industry are the inventions of A. I. Stamsvik of Pittsburgh, a Trondhjem graduate who came to America in 1926. His process of pasteurizing milk is now considered best and most efficient and is standard over all Canada and the United States. Stamsvik's method grew out of the invention of a heat exchanger that he originally used as a cooler for lubricating oil. Licenses under Stamsvik's patents have been sold to several manufacturers, for some of whom he has been consulting engineer. One of his latest inventions is a cold raw filter which he himself began to manufacture in a small plant in Grove City, Pennsylvania. The business grew so rapidly that he moved the firm to Pittsburgh in 1941. The filter machine, which is also used for cream and ice cream mixtures, has been approved by the department of agriculture and the health departments of the forty-eight states as the finest now in use.[15]

It has been mentioned that many Norwegian engineers have been employed by the Great Northern Railway in St. Paul. One of this group, Georg B. Anthonisen, has invented a new kind of railroad track. He has experimented with rails, spikes, and tieplates. Several features of the resultant track, which he hopes to see adopted, are: a twisted spike, which the inventor claims gives up to 70 per cent more resistance to pulling than the present standard straight-cut spike; a rail with concave base; tieplates with a key arrangement; and clearance of the rail flange by the spikes, which reduces the forces normally loosening the spikes. Anthonisen, a graduate of the Ilmenau Polytechnicum, also invented a basically new propulsion method and a new tank principle, both of which have been carefully studied by the navy. Since the latter are allied with national defense, no attempt has been made to patent them.[16]

Typical of the many Norwegian machinists who have made

[15] *Nordisk tidende*, April 9, 1942; *Norwegian-American Technical Journal*, vol. 11, no. 2, p. 10 (December, 1938).

[16] Information supplied by Anthonisen. See also *Norwegian-American Technical Journal*, vol. 10, no. 1, p. 8 (February, 1937).

lasting contributions to American industry is Oscar Onsrud, now proprietor of the Onsrud Machine Works of Chicago. He came to the Midwest in 1893, a victim of "America fever" who was eager to see the Columbian Exposition. Onsrud worked many years for the Frazer and Chalmers Machine Company as machinist, as traveling representative in the United States and Mexico, as foreman, and, in 1912, as superintendent of the plant. Later starting out independently, he worked on machine improvements and produced a new type of turbine which he has sold by the thousands. His plant was opened in 1924 and soon had about 75 men employed in the making of various products. Onsrud is also the inventor of automatic shaping machinery for furniture factories. A piece of wood inserted into one of these machines comes out a perfectly shaped table leg or chair arm. Many of the sofas and chairs in American homes today are made by his patented process, as are such items as clothes hangers and the wooden handles on kitchen utensils.[17]

III

A considerable group of important mechanical engineers have not yet been introduced into our story. The list includes Harald F. Gade, member of a famous Bergen family, who is known as the "grand old man" in Philadelphia circles. He received his technical education at the Bergen and Charlottenburg schools and came to America in 1896. Gade became vice-president and one of the founders of the Standard Pressed Steel Company in 1903, after working for such firms as the Baldwin Locomotive Works, William Sellers, and the New York Shipbuilding Company. His company employs over 2,000 workers and produces a variety of articles in addition to pressed steel. Gade made a specialty of pressed steel and screw machinery and took out several patents. Another of his products was the so-called Gast system for automatic oil lubrication.[18]

Scandinavian glassworkers have an honored history at Corn-

[17] *Skandinaven,* March 10, 1936.

[18] Wong, *Norske utvandrere,* 150; archives of Norwegian-American Technical Society, Chicago; *Nordisk tidende,* November 25, 1943.

ing (the "Crystal City"), New York. The first Norwegians went to this town in 1903, some time later than the Swedes and Danes. Alfred Vaksdal, plant engineer of the Corning Glass Works, is one of a small trickle of skilled immigrants to this region. Vaksdal, one of the most colorful of the living Norwegian engineers in America, graduated from Horten in 1907. While employed by the American Briquet and American Wood Reduction companies of Chicago and Kingsport, Tennessee, Vaksdal worked out processes patented by the companies: one for briquetting brass and iron borings, another for briquetting sawdust, and a third for extracting wood alcohol from wood refuse. He began his association with the glassworks in 1922 and was put in charge of all plants and made responsible for engineering, construction, and general operation. In the years that followed, his firm went through a great period of expansion, building a complete new plant at Central Falls, Rhode Island; enlarging the plant at Wellsboro, Pennsylvania; reopening a plant at Kingsport, Tennessee; constructing a new automatic glass tubing plant, another for the manufacture of glass wool and glass cloth, a third for the production of glass brick, and yet another for the automatic manufacture of Pyrex ovenware. Vaksdal played a leading role in this growth of the glass industry.

In 1931 the California Institute of Technology ordered from the Corning Glass Works a glass disk of low expansion and sufficient size to make a telescope mirror 201 inches in diameter. It was, if possible, to weigh much less than it would if the customary principle of a thickness of one-sixth the diameter were followed. The disk has been placed in the giant telescope on Mount Palomar. The problems involved in filling the order were largely engineering difficulties occasioned by the great size and weight of the disk; the existing glass technology was sufficient to meet the challenge, once the necessary engineering details were perfected. The glass was melted in a tank, transferred to a mold in large hand-operated ladles, and annealed in a periodic, electrically-heated kiln. The problems arising from

this project and the story of how they were met have been admirably described by Dr. G. V. McCauley, who was in charge of the undertaking.[19] Vaksdal and his assistants played a big part in building the disk; the plant engineer was co-designer also of the mechanical and electrical apparatus employed. All engineering features of the job were smoothly accomplished.

On one occasion Vaksdal had to deal with an "act of God." Early in July, 1935, cloudbursts and a dam break on one of the Finger Lakes caused the Chemung River, which flows past the Corning works, to rise 18 feet above normal, submerging motors and curtailing glass production. The fight to maintain power services and to protect the giant telescope disk, the "Great Eye," is vividly described by Vaksdal in *Power*.[20]

George S. Hoell, a graduate of Trondhjem who served as a machine designer with the E. G. Budd Manufacturing Company in Philadelphia, has had a varied technical experience and has made several noteworthy contributions: a bending machine for reverse curvatures and a special electric welding machine, both of which are patented by the Budd company; and a special beater for hammermills, which was patented by the Pennsylvania Crusher Company.[21] Frederik Ottesen, who was educated in Bergen and Munich and who is now consulting engineer with E. I. DuPont de Nemours and Company at Wilmington, is the inventor of a gas-engine valve gear known as the butterfly gear and of a clear-vision sight-feed oiler, both of which are patented.

Henry Karl Karlsen attended the Porsgrund and Horten schools and in 1919 designed for the Hanneborg Company of Christiania a well-known tile-trenching machine. For the

[19] "The 200-Inch Telescope Disc," in Society of Glass Technology, *Transactions*, 19:156 (1935); "Making the Glass Disc for a 200-Inch Reflecting Telescope," in *Scientific Monthly*, 39:79–86 (July, 1934); "Preparing to Look Farther into the Universe of Stars," in *Telescope*, 1:34–44 (June, 1934); and "Some Engineering Problems Encountered in Making a 200-Inch Telescope Disk," in American Ceramic Society, *Bulletin*, 14:300–322 (September, 1935).

[20] Vol. 79, p. 422, 454 (August, 1935). The present writer is indebted to Vaksdal for considerable information.

[21] Alstad, *Trondhjemsteknikernes matrikel*, 169; and information furnished by Hoell.

French government he devised a digging machine that could be attached to unused war tanks. In 1929 he came to America; he was employed by the Mergenthaler Linotype Company and later by the International Business Machines Corporation. One of his many inventions is a so-called diff-system for differential gearing.[22]

Among other recent arrivals, several mechanical engineers have already done outstanding work. A Horten man, Georg J. Langmyhr, mechanical development engineer with the Imperial Oil Company of Sarnia, Ontario, has been active in the development of oil-well drilling machinery at Corsicana, Texas, and oil refining apparatus in Ontario. At least 5 of his inventions in the latter field have been patented in Canada and the United States. Ole I. Stangeland is designing engineer for the Foote Brothers Gear and Machine Corporation in Chicago; he has been in charge of standard power transmission designs, special designs for bridges, steel mills, dams, and all types of gearing and power transmission machinery used in modern industry. With Arne Faroy he patented, in 1929, a piston and cylinder cooler for internal combustion engines, and in 1934 he patented a free-wheel and backstop device now being marketed.

In recent years a number of graduates of Norway's Institute of Technology have assumed prominent positions as mechanical engineers. Among them is Alf Kolflat of Sargent and Lundy in Chicago. Completing his course at the institute in 1919, Kolflat spent two and a half years in the special laboratory study of heat and steam, enjoyed a stipend for travel in Germany (another grant from the institute), and made tests of houses for the Norwegian government. Finally in 1923 he left for America on a grant from the American-Scandinavian Foundation, spent a short time at the Massachusetts Institute of Technology, and then took employment in industry. In 1925 he joined Sargent and Lundy, a Chicago firm specializing in the design of steam power plants, and eventually became a

[22] *N. E. S. Bulletin* (a publication of the Norwegian Engineers' Society), no. 2, p. 25 (Brooklyn, December, 1939).

partner in the company. Active in the social and technical life of the Norwegians, Kolflat has co-operated on a number of industrial and central-station power plants throughout the Middle West and has invented an apparatus that determines heat losses through building walls. He has also served as president of both the Norske Klub and the Norwegian-American Technical Society of Chicago.

Illustrative of the many other mechanical engineers doing significant work in America are Harold M. Mikkelsen, who is in charge of the car dumper department of the Roberts and Schaeffer Company of Chicago; Reidar A. Tollefsen, assistant chief engineer of the United States Gauge Company at Sellersville, Pennsylvania; and Knut E. Grundvig, who occupies a position similar to Tollefsen's at the Bucyrus-Monigham Company of Chicago and has participated in the development of the modern dragline excavator. The Olsen Testing Machine Company has always employed many Norwegian engineers; one of these, Jens Sivertsen, is a research and development specialist who has invented among other things a method and an apparatus to determine unbalance in rotating bodies, and an automatic balancing machine. Frederick W. Guilford, mechanical engineer in the Flint, Michigan, office of the Trane Company, has installed air conditioning in no less than 150 theater buildings. Mikkelsen, Grundvig, Sivertsen, and Guildford are all graduates of Norway's Institute of Technology; Tollefsen is a graduate of Horten.

IV

The Norwegian engineer's part in the development of the Diesel engine in America has been relatively small, yet it is worthy of record. Henrik Greger, a Trondhjem graduate, was a marine engineer for the United States Shipping Board during the First World War and since then has served as chief engineer of the General Machinery Corporation at Hamilton, Ohio; in both capacities he has been closely associated with Diesel developments. Olaf L. A. Riegels, a Horten man, spent

a good part of his technical life in Christiania, Norway, before coming to America in 1924; after 1934 he was engaged in research and experimental work at the Yoder Company in Cleveland, where he specialized in the hydraulic wave balance of pressure fluctuations in injection systems of direct-injection Diesel engines. Riegels' contributions include a lubricator which was sold to a Hamburg firm; a direct reversing arrangement for internal-combustion engines, patented in the United States; and fuel injection means for motors, which have been patented in various countries. The last invention is believed to be of far-reaching character in that it will provide for a constant pressure combustion cycle with direct injection—a feature termed impossible by Dr. Diesel.[23] Bernhard Haave Andersen, a graduate of Norway's Institute of Technology, has also been a development engineer and calculator of Diesel engines; in 1936 he became research engineer in the Diesel division of the Baldwin Southwark Corporation of Philadelphia. Andersen's specialty is torsional vibration problems and he has served as a member of the technical committee of the Diesel Engine Manufacturers' Association, which was appointed to simplify and standardize the methods of calculating parallel operation, torsional vibrations, and the like, for the successful operation performance of Diesel-generator installations.[24]

V

The work of Mauritz Indahl in the field of printing has already been discussed. Considerably earlier than Indahl, Hans Christian Hansen migrated to America, shortly after completing his studies at Horten in 1867, and took employment with the Dickenson Type Foundry in Boston. Four years later he established the H. C. Hansen Type Foundry. A branch of the firm was opened in New York under the direction of his son, Alfred, and offices were maintained in several cities. Hansen designed and built all the special machines and tools for

[23] Information supplied by Riegels.
[24] Information from the Chicago archives of the Norwegian-American Technical Society.

the production of his well-known type and other printing materials, taking out patents on many inventions.[25]

Several other Norwegian engineers figured in the development of American printing. Hans Jordhøi, a graduate of the Porsgrund school, was long employed by the Wood Printing Press Company at Plainfield, New Jersey, and his work with printing presses resulted in a long list of patents on machines of this type. Severin Halvorsen, another Porsgrund graduate, invented the inserting machine that is used by large daily newspapers in putting out special Saturday and Sunday editions. This actually consists of six successive mechanisms, and its function is to feed the special edition with such supplements as the pictorial, comics, style, and sports sections.[26]

Gustav Olsen, chief engineer with the Western Printing Company of Chicago, was widely sought by publishers and printers alike because of his skill with printing machinery. At the time of his death, in 1934, he had just completed an advisory job in Alabama.[27]

VI

In 1928 there appeared in the Norwegian press an unusual story. According to it, the once popular Overland automobile was created by one Johan Øverland, who also built the first factory to adopt the principle of mass production. Øverland, the son of a smith in Christiansund, was, we are told, of the Peer Gynt type. He migrated to America on an impulse, spent ten years at various jobs, and then returned to his home in Norway, where he became a reputable craftsman specializing in iron stairway railings. The young dreamer was dissatisfied with his lot in Europe, however, and left again for the New World, going this time first to Canada. When Øverland arrived in America the automobile was only just coming into practical being and his imagination was captured by its possibilities. He designed the Overland car and started a factory at Toledo which set as its goal the production of cars at popular prices.

[25] *Femti-aars jubilæums-festskrift, Hortens tekniske skole,* 99.
[26] *Skandinaven,* October 25, 1932.
[27] *Scandia,* November 1, 1934.

His company, later known as Willys-Overland, by 1928 had plants in Toledo, Pontiac, Toronto, and Stockport, England; the daily production at Toledo alone was 3,000. The sons of Johan Øverland later became technical directors of the factories, while the business management passed into the hands of the president, J. N. Willys.[28]

This legend is repeated here because it illustrates the difficulty of tracing origins and also the caution with which one must use the newspaper as a source. Frank H. Canaday, who has done considerable research in the early history of the Willys-Overland Company, states that his investigations, "insofar as they touched on Willys-Overland's predecessor, the old Overland Company in Indianapolis, indicated that the Overland name came from the old pioneer Fargo line of stages called the Overland Express."

> I have never heard of anyone of this name being connected with the Willys-Overland Company organized by Mr. John North Willys after his purchase of the original Overland Company of Indianapolis in 1908, nor in the present Willys-Overland Motors, Incorporated, as reorganized in 1936. I can say with reasonable certainty that there has been no one of the Overland name associated with the organization since it became a factor of importance in the industry after 1908.[29]

Delmar G. Roos, vice-president in charge of engineering at Willys-Overland, supports Canaday's remarks about the naming of the automobile, using the phrase "Overland Mail"; he speaks, too, of the Overland Limited, a train operated by the Union Pacific between Chicago and San Francisco and running on schedule as a crack flyer before the Overland car went into production. His conclusion, like Canaday's, is that "if there was a Johan Overland connected with the Company, it was a coincidence."[30]

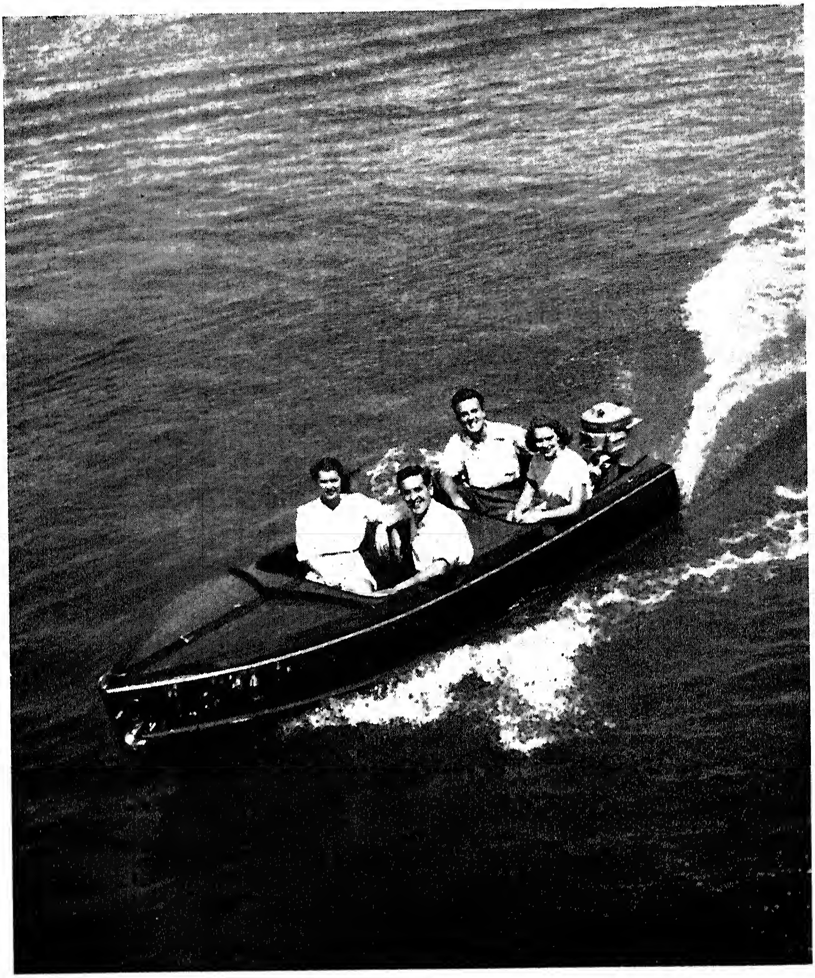
Norman G. Schidle, executive editor of the *S. A. E. Journal* published by the Society of Automotive Engineers, Inc., of New York City, confirms the views of Canaday and Roos. From

[28] *Nordisk tidende*, August 2, 1928; *Nordmands-forbundet*, 21:348 (1928).
[29] Letter to the writer, November 15, 1945.
[30] Letter to the writer, November 19, 1945.

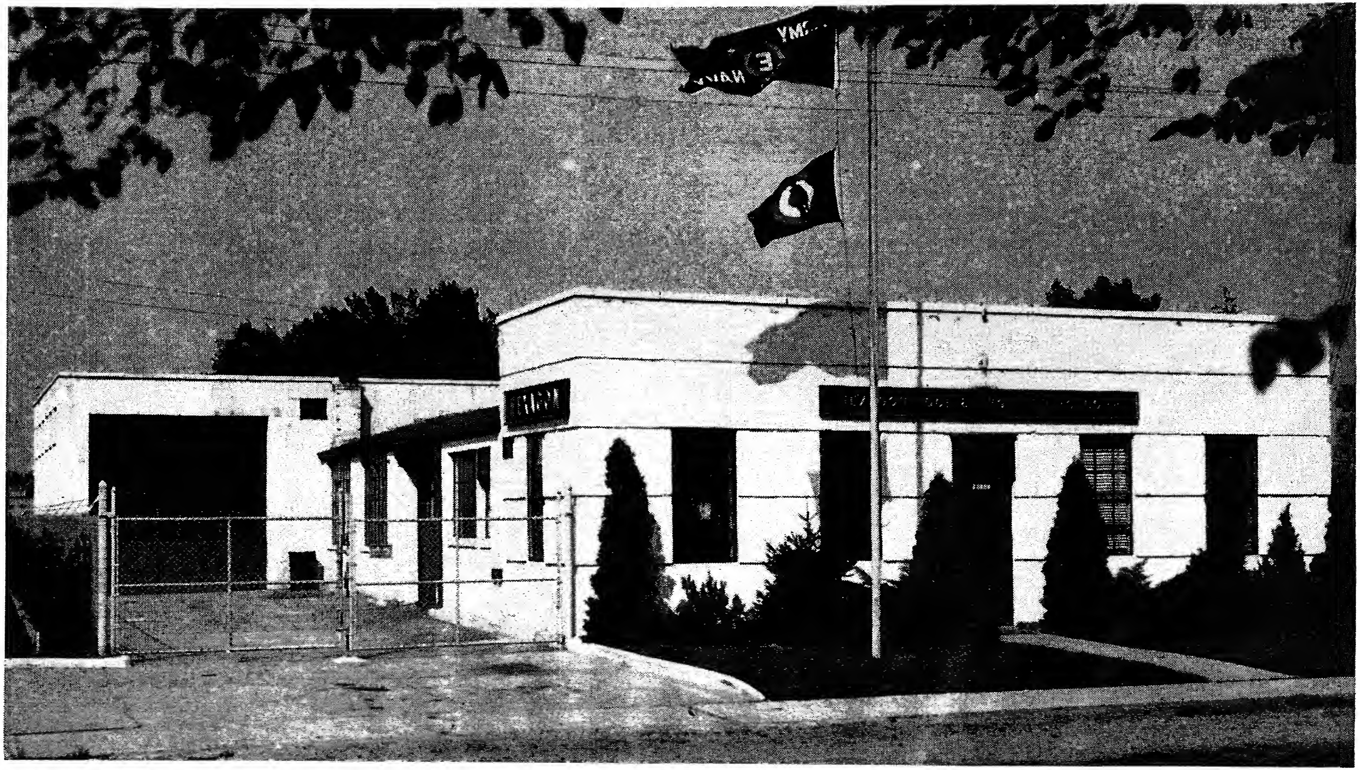
records in the possession of the society he finds that the original Overland car was made in 1903 by the Parry Buggy Company of Indianapolis and that its name "was taken from the Overland Stage Coaches." Nothing is known of an engineer named Øverland.[31] Data contained in the automotive history collection of the Detroit Library "seem to indicate that it [*the Overland*] was built by the Standard Wheel Company of Terre Haute, Indiana, about 1902. D. M. Parry was the head of the Company and the chief engineer was Claude E. Fox. In 1913 the vice-president of the Willys-Overland Company, G. W. Bennett, could not say why the directors of the Company had chosen the name Overland but surmised it was because of the car's ability to go 'over land.'"[32] Neither these nor other records make any mention of Johan Øverland, and one is therefore forced to conclude that he was fabricated of whole cloth by some journalistic prankster.

The men who built the first automobiles were engineers only by courtesy; they were craftsmen or mechanics of a highly gifted sort. The same is true of Ole Evinrude, who went to Wisconsin with his parents at an early age, grew up on a farm, and made his technical start in a farm machinery shop at Madison. Through experience and study he became an excellent machinist. At Milwaukee, during the early years of this century, Evinrude became interested in internal combustion engines and entered into a partnership with a man named Clemick, to produce engines and parts to order. He later went into a second partnership which aimed at manufacturing a standardized motor that could be installed in any carriage. Ole left this firm, the Motor Car Power Equipment Company, when his partner balked at marketing an entire automobile built by Evinrude. One year later Evinrude put together a second car which he called the Eclipse; with the help of two men who consented to finance the production of complete automobiles, he

[31] Shidle to Roos, November 26, 1945; a copy of the letter was forwarded to the present writer.
[32] Carl E. Pray, Jr., to the writer, February 7, 1945.



An Evinrude Motor in Action



A Typical Small Tool Works: N.H.F.Olsen, Dearborn, Michigan

began a third business venture, which proved unsuccessful. Evinrude later turned his abundant energies and skill to perfecting, in 1910, the first practical outboard motor bearing his name, and won both fame and fortune in this new field.[33]

One of the best-known Norwegian engineers in Detroit before his death in 1929 was Trygve Jolstad, assistant general manager of the Briggs Manufacturing Company. Jolstad, a graduate of Horten, arrived in Detroit in 1915 and soon became factory manager of the Michigan Stamping Company; he held this position until the company was absorbed by the Briggs concern four years later. As assistant general manager of all the Briggs plants, Jolstad had an important part in the development of automobile bodies. Like the automobile itself, his industry underwent rapid growth from 1915 to 1930.[34]

Another colorful Detroit engineer, N. H. F. Olsen, a Porsgrund graduate, was associated with Henry Ford from 1915 to 1940. Starting in the production department, he was transferred in 1918 to the engine division, where he worked at designing gasoline tanks. Continuing as a layout man, checker, and designer, he was sent from division to division — Ford chassis, body, experiment, tractor, truck, aircraft, Lincoln chassis, and so forth. About 1930 Olsen organized the experimental department and had charge of following the experimental work through, from designs to the ordering of parts and the construction of experimental cars. In 1936 he organized the sound-test division and worked with engineers at the University of Michigan on noise problems. Olsen patented a number of processes, several of which are still being used by Ford. They include an alemite system for greasing springs, a drive shaft construction with center bearing, and a stabilizer which improves the riding qualities of a car. The last was a feature discussed in the advertising of 1940 and 1941 Ford and Mercury models. Olsen also cut down car noise considerably, helped plan the Ford proving grounds in 1938, and invented the drop-

[33] See the present writer's article, "Ole Evinrude and the Outboard Motor," in *Norwegian-American Studies and Records*, 12:167–177 (1941).

[34] *Norwegian-American Technical Journal*, vol. 3, no. 1, p. 11 (February, 1930).

center wheel and rim used on Ford cars from 1926 to 1932 and adopted by the Tire and Rim Association of America.[35] During the war years Olsen operated the Hexagon Tool and Engineering Corporation in Dearborn; for the excellence of his work in producing artillery items, he was twice presented army-navy production awards.

Mention is made elsewhere of the work of E. K. Wennerlund, who served as director of production engineering in all plants of the General Motors Corporation. His association with this firm began in 1911, shortly before William C. Durant became president and at a time when the company was in the hands of the bankers; it ended with his retirement in 1932. Wennerlund's objective, as he expresses it, was "to make production flow like a river." In this he was successful.

The automobile, like any complicated industrial product, represents the contributions of many individuals, engineers and others. Typical of the many Norwegian engineers who have added improvements is Trygve Vigmostad, body engineer at the Briggs Manufacturing Company. After several years' experience in Germany and Norway, Vigmostad came to America and held various engineering jobs before assuming his present position. While employed by the Murray Corporation of America, he patented the curved-edge window design. Vigmostad studied at the Christiansand Technical Evening School, at a trade school in the same city, and at the Hamburg Technical Institute.[36]

Of a piece with the automobile is the tractor, to which development John A. Riise made a lasting contribution. Riise, a born inventor, devised a new-type musket while still in Norway; some of his early ideas in this field were later adopted by others in the Browning machine gun. After coming to America in 1902 Riise became a draftsman in an automobile factory on Long Island. He turned to various tasks, producing, among other things, a boat. His chief interest, however, was the new

[35] Materials in archives of Norwegian-American Technical Society, Chicago; information received from Olsen.

[36] Information supplied by Vigmostad.

gasoline motor, and his inventions in this field proved profitable to several firms, including Palmer Singer in New York; the Waltham Manufacturing Company in Massachusetts; General Electric; the Pope Manufacturing Company at Hartford, Connecticut; and the International Harvester Company at Chicago. His most productive period was with the Wellman, Seaver, Morgan Company, an engineering firm at Cleveland. This company was greatly interested in a tractor that Riise had invented, and gave him free use of machines, tools, and men to enable him to put it into concrete form. As a result he turned out what was considered in its day one of the country's finest tractors; it created wide interest when it was demonstrated at the Kansas City Exposition of 1920. Riise and his firm, convinced that the tractor was ready for mass production, organized a separate company, the W. S. M. Tractor Corporation, and began manufacturing at Akron. Riise, a man of tremendous energy, also invented features that were incorporated into airplane motors, gears, transmissions, and axles of various kinds.[37]

VII

Several of the Norwegian engineers gave special service to this country through the production of munitions and other implements of war. The earliest of the group was perhaps Alfred Christiansen. After putting in a hard period at sea and in the machine shop, Christiansen went through Christiania's Technical College. He arrived in Philadelphia in 1880 and, like many others, worked for the Baldwin Locomotive Works and for William Sellers. Later he was employed by Brown and Sharpe at Providence and by the Hinckley Locomotive Company in Boston, and in 1883 he transferred to the Watertown Arsenal. Ordered to the Watervliet Arsenal, Christiansen became master mechanic of the newly completed gun factory. His last project, before his death in 1903, was the completion of the largest coast defense gun in the world.[38] Among others who have

[37] Wong, *Norske utvandrere,* 170; *Nordisk tidende,* October 1, 1920; materials in archives of Norwegian-American Technical Society, Chicago.

[38] American Society of Mechanical Engineers, *Transactions,* 24:1542 (1930).

worked in government arsenals are F. M. Brauer, a graduate of Horten and an engineer at Watertown; and John Crossen, a 1922 graduate of Christiania's Technical College, who is serving at the Edgewood Arsenal in Maryland.

The airplane has become one of the deadliest of war weapons, and in its development European-trained Norwegians have had some part. Knut Henricksen, for example, was responsible in 1937 for the construction of a four-motored navy bomber at the Sikorsky plant; this plane, an amphibian, weighed 27 tons and was labeled the largest of its kind. John Christian Hanson, a graduate of the technical institute at Ilmenau, is a designer at the Republic Aviation Corporation, Farmingdale, Long Island. He was project leader in charge of the 18 men who redesigned the Sikorsky S-41 amphibian in 1940.

Of the Norwegian engineers who participated directly in the American attack against the Japanese, none had a more brilliant military career than Leif J. Sverdrup. Though he was born and partially educated in Norway, Sverdrup attended Augsburg College in Minneapolis and the University of Minnesota. Completing the course in civil engineering at the latter school in 1921, he served with the state highway departments of Minnesota and Missouri. In 1928 he formed the partnership of Sverdrup and Parcel, consulting engineers, at St. Louis.

In 1941, while still a civilian, Sverdrup was chosen by the army to select a ferry route for American airplanes to the Philippines and another to Australia. At the time of Pearl Harbor, he was in the Fiji Islands; almost at once B-17 bombers began to make use of the route he had chosen. He laid out a highway from Melbourne to Darwin, and many airfields in Australia. The speed of the Japanese advance forced him to find an alternate airplane route. In May, 1942, Sverdrup became a colonel in the engineer corps; two years later he was promoted to brigadier general; and in 1945 he received the rank of major general. He became commanding general of the Engineer Construction Command under General MacArthur.

Though best known today for his important military work

in the Pacific, Sverdrup also directed the designing and construction of the Jefferson Barracks Bridge near St. Louis, and the Mark Twain Memorial Bridge in Hannibal, over the Mississippi; the Weldon Springs Bridge near St. Charles, Missouri, and the McDaniel Memorial Bridge near Miami, Missouri, over the Missouri River; and the Miraflores Locks Bridge over the Panama Canal. Before and during the recent war his firm also undertook such projects as aircraft factories, repair depots, wind tunnels, steel plants, shipbuilding plants, airdromes, and auxiliary installations in the Pacific islands and Australia, as well as pipe lines and refineries in Canada.[39]

VIII

The number of Norwegian engineers employed in the gas and coke industries is relatively small, but several have had a notable influence. John Samuel Unger, a graduate of Trondhjem's Technical College, came to America in 1879. In 1905, after several positions with gas companies, he became city engineer at Manitowoc, Wisconsin; and in 1907 he opened a firm in Chicago to manufacture the patented Unger ammonia stills, now used by various gas works and coke ovens in Canada and the United States.[40]

Olaf N. Guldlin, who emigrated to the United States one year later than Unger, was a graduate of Bergen's Technical College and a student at the Munich Polytechnicum. He lived in Fort Wayne, Indiana, from 1884 until his death in 1932. In 1888 he formed with two other men a partnership of consulting gas engineers; two years later it was incorporated, after changes in partners, under the name Western Gas Construction Company, with Guldlin as president and general manager. In 1917 the Koppers Company of Pittsburgh took a five-year lease on the firm; they purchased it in 1922 and Guldlin retired as president but continued as a member of the board of directors.

[39] Information supplied by Sverdrup; *Nordmanns-forbundet,* 38:382 (1945). See, too, Sverdrup's article, "Nakne fakta fra Ny Guinea," in *Nordmanns-forbundet, Julen 1943,* p. 15–26.

[40] Alstad, *Trondhjemsteknikernes matrikel,* 19; *Scandia,* March 10, 1938; materials in the archives of the Norwegian-American Technical Society, Chicago.

Despite his business and managerial experience, Guldlin's chief work was technical. He designed and patented about 50 devices, including a gas condenser, a coal-treating apparatus, an ammonia washer, and numerous governors and valves for use in the gas industry. He won a grand prize at the Louisiana Purchase Exposition in St. Louis, 1904, in recognition of his inventions and developments. At the San Francisco Panama-Pacific Exposition in 1917, Guldlin was honored with a gold medal on the recommendation of the American Gas Institute. He retired in 1922.[41]

Halfdan Lee (Lie), well-known president of the Eastern Gas and Fuel Associates of Boston, has also been an important factor in the gas and coke industry. A graduate of the technical schools at Porsgrund and Ilmenau, Germany, Lee came to the United States in 1908. Until 1916 he was chiefly engaged in plant expansion in the steel industry. From 1916 until the late 1920's he was with the Koppers Company, serving in varying engineering capacities, and eventually he became vice-president in charge of sales. These were transition years in the coke industry, when by-product ovens built by the firm were replacing the old-style ovens. The Eastern Gas and Fuel Associates, which Lee now heads, operates coal mines, coke plants, blast furnaces for the production of pig iron, and a steamship company operating a large fleet composed mostly of colliers.[42]

IX

Another group of engineers has had an influence, largely mechanical, in mining and its related activities. Nils Cornelius Bonnevie, a former student of Trondhjem's Technical College, began his American career by helping Viggo Drewsen introduce his patents on this side of the Atlantic. In 1896 Bonnevie was employed by the Metallic Extraction Company of Florence, Colorado, and later he took an important technical position with the Doreas Mining, Milling, and Development Company

[41] American Society of Mechanical Engineers, *Transactions*, vol. 54, record and index, p. 62 (1932).

[42] *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 12 (March, 1929); *Nordmands-forbundet*, 24: 384 (1931).

of the same city. Finally, in 1900, he became director of the Denver Ore Testing and Sampling Company of Denver, and there supervised the testing — chemical and mechanical — of all kinds of minerals on a scale unmatched elsewhere.[43]

Another Trondhjem graduate, Christian Strøm Holth, left the Chicago engineering office of the federal government to serve, in 1905, as chief engineer of the Brazilian Diamond, Gold, and Development Company. His work consisted of surveying concessions, determining values, and making preparations for later mining activity. Returning to federal employment in the States, he later worked on such Mississippi River projects as the Keokuk Dam, and gained a reputation as a prominent mechanical engineer. It is interesting to note that while in Brazil Holth was known among the natives of fever-ravished districts as Dr. Christiano, because of his kindly interest in the sick and the remedies that he was able to provide.[44]

Charles C. Hansen had been mechanical engineer with the Ingersoll-Rand Company of Phillipsburg, New Jersey, for thirty-five years when he died in 1938. He is credited with over 100 patents on compressed-air tools and other drilling equipment. Hansen studied at the Norwegian university and at the technical schools of Berlin and Zurich, becoming a specialist in marine engineering. After spending several years in the early 1890's along the Canadian side of the Great Lakes, he was employed on the New York Barge Canal. Later he was associated with a firm manufacturing Corliss steam engines used to drive air compressors, and he went to Ingersoll-Rand in 1903 and assisted in the construction of their Phillipsburg plant. When transferred to the rock drill engineering department, Hansen was put to work perfecting tools used extensively in mining and canal construction. He designed, among others, most of the drills used on the Panama and New York Barge canals.[45]

[43] Alstad, *Trondhjemsteknikernes matrikel*, 85.

[44] Alstad, *Trondhjemsteknikernes matrikel*, 17; *Norwegian-American Technical Journal*, vol. 2, no. 1, p. 15 (March, 1929); *Minneapolis tidende*, November 22, 1911.

[45] *Decorah-posten*, July 5, 1938; and information supplied by Hansen's associates at Ingersoll-Rand.

Mention of a few of the others engaged in mining activities will suffice to indicate the scope of their work. Nils A. Bodahl, a graduate of the Trondhjem college, was once chief engineer at the copper mines in Butte, Montana, and later an employee in the Carnegie steel mills near Pittsburgh.[46] Bjørn Rudolf Storsand, a graduate of the technical school at Mittweida, in Germany, is chief designing engineer of the Placer firm of San Francisco; he holds a number of patents in connection with dredges and mining processes. His dredges, for both tin and gold, have been used in various countries. Einar Martin Arentzen, president of the Lee-Norse Company of Charleroi, Pennsylvania, and a 1915 graduate of Trondhjem's Technical College, was responsible for numerous improvements in mechanical coal-loading machines while chief mechanical engineer for the Joy Manufacturing Company of Pittsburgh, 1924–40; he has been closely identified with all important developments in the mechanical loading of bituminous coal underground. His own company, founded in 1940, engages in the manufacture and sale of all kinds of coal-mining machinery, particularly the type which, mounted on pneumatic rubber tires, is used in mining bituminous coal. And, finally, Halvor Hansen Hanto, a structural engineer in the mining department of the Bethlehem Steel Company, has figured prominently in the design of mining plants in Chile and Venezuela as well as of ore-crushing plants in the United States. Hanto is a graduate of Norway's Institute of Technology.

X

How limitless the engineering story has been and how numerous are its associations is perhaps best revealed by reference to a few more individuals, who deserve better than the passing comment reserved to them in this volume.

Heitman J. Altern, a graduate of Horten, while employed by the Raymond Lead Company of Chicago early in the present century, designed a tower for the manufacture of lead shot to be used in shotgun shells. The tower, erected at Port Amboy,

[46] *Minneapolis tidende*, December 8, 1932.

New York, could produce 150 tons of shot in twenty-four hours. Hans Hammeren, who attended Christiania's Technical College and later served as structural designer for the Bethlehem Steel Company, holds patents on floating roofs for gasoline and pressure tanks. Theodore Laws, now part owner of a Chicago firm, had an important part, as an employee of the Burrell Engineering and Construction Company, in the design and construction of some of the largest stone-crushing plants in America, not to mention grain elevators, cement plants, flour mills, and other industrial buildings. Laws is a graduate of the technical schools at Bergen and Dresden. Alf Selrod, of Trondhjem's Technical College, patented an ice machine when such a product was new on the market; more recently he has been active in designing heating and ventilating systems for numerous buildings erected by Graham, Anderson, Probst, and White in the Chicago loop district. Earlier, with the sanitary district, he designed the ventilating systems used in pumping stations, as well as a sewage disposal plant. Selrod has been a most active leader in the social life of the Chicago Norwegian engineers.

The work of such men has been, of course, more or less routine. Somewhat more colorful were the professional activities of several others belonging to our story. Thorleif Bjarne Jørgensen, another graduate of Trondhjem's Technical College, was in charge of the erection of an automobile factory at Nizhnii Novgorod, about 350 miles east of Moscow; this plant, finished in 1932, was able to produce some 100,000 cars per year. While Jørgensen was in Russia, he also assisted in the construction of dwellings and other facilities for workers. Upon his return to the States, he constructed a factory at La Grange, Illinois, where modern streamlined locomotives are built.[47] The varied experiences of Henrik Naglestad Garson, a Horten man, include the construction of an automatic mechanical electric traffic control apparatus introduced in Buenos Aires, and direction of the plant of Mineral El Teniente, Braden Copper Company, in Chile. Another Horten graduate, Christofer Braathen, repre-

[47] *Skandinaven,* December 9, 1938.

sented the engineer group during the first Byrd expedition to the Antarctic as ski expert, musher, and machinist, and was cited for his services. More adventurous still, Claus Jeldnes, a self-taught mining engineer and geologist, was sent to Svalbard (Spitzbergen) by the Arctic Coal Company of Boston, and while there, is said to have hoisted the American flag and claimed the territory for the United States. Earlier, he was considered one of Canada's leading ski jumpers.[48]

XI

It is both interesting and profitable to look more closely into the life of a representative mechanical engineer, to discover how his work has influenced industrial development, and how, after retirement, he judges the activities of a busy life devoted to technical pursuits.

Jonas Lien was born at Lesjaskog, Gudbrandsdalen, in 1877. He graduated from Christiania's Technical College in 1901, with the degree of civil engineer. In 1902, disappointed over the meager prospects for advancement within the Norwegian state railway system, with which he had been briefly associated, he left for America. Lien first found employment as a draftsman with an engineering and contracting firm in New York, then worked for relatively short periods with several steel and bridge companies before beginning a long association, from 1920 to 1942, with the American Gas and Electric Company. He now lives in retirement at Port Washington, New York.

Lien, at the request of the present writer, has reluctantly prepared a lengthy statement of his experiences in America. Because they are typical of many able engineers, they are of uncommon historical value. "The localities in which I was employed during the first two decades of my practice in America," he writes, "had no institutions giving technical courses, so what otherwise might have been convenient years for post-graduate studies went without opportunities for me to accumulate academic credits." But for forty years he studied technical

[48] *Reform* (Eau Claire, Wisconsin), May 30, 1935.

literature and applied these studies to his varied practice; at the same time he closely observed the operations of American industry, and came to understand "their needs for better methods and equipment in order to introduce practical improvements." His employers derived material benefits from his successes, and Lien "gained knowledge and benefited indirectly, both professionally and financially, through an occasional promotion."

Of inventive mind, he prepared a number of novel designs for the companies that employed him. These were significant because they made it possible for his firms to win contracts in highly competitive fields. Lien's satisfaction came from the fact that he was "invariably called on to work out or give advice in solving new problems with which no one in particular had had any previous experience, as well as to find more practical applications of and improvements on existing devices not previously perfected."

Lien, partly because of the demands of his position and partly because of interest, made specialties of certain branches of electrical and mechanical engineering. "These branches," he recalls, "more and more overlapped my original specialty, which was in the structural field." He was soon designing "erection equipment for heavy structures and operating machinery for swing and lift bridges"; later it was "heavy material-handling equipment for big industries in general, when the fabricating concerns with which I was associated branched out from the more specialized building of bridges to serve the growing demand for industrial plant structures in such fields as that of the automobile."

His early studies and experiences while employed by steel and bridge firms stood Lien in good stead when, in 1920, he was called to the New York office of the American Gas and Electric Company. He was assigned to plan a new coal-handling system for their largest power plant—"the first up-to-date large-capacity (600 tons per hour) coal-handling system in this country conveying the coal by belts directly from the

mine to the overhead bunkers in the power house; the system was linked with rail and barge unloading facilities as well as with facilities for discharging surplus coal into a 120,000-ton reserve storage and for reclaiming it as needed, and also with equipment for crushing and screening the coal into suitable sizes for stokers." Until then power plants had been dependent on cumbersome and costly methods of handling their fuel; these had required "much manual labor operating with multiple systems of small-capacity units of light commercial equipment. The tonnage cost of handling the coal even from nearby mines into the bunkers would therefore at times exceed the cost of the coal itself, a situation further aggravated by too frequent breakdowns of the poorly designed and crudely built equipment involving delays endangering continuous operation of the boilers." The new system reduced the cost of handling coal by one dollar per ton. The plant burned as much as 1,000 tons per day.

Lien not only had to prepare the plan of the general system, but was also charged with the more difficult task of developing detailed designs of the special equipment that was involved. "What the market had to offer," he relates, "was mainly suitable for limited use in small-capacity installations." Belts of the required width and length were at first unobtainable, but a progressive rubber manufacturer finally co-operated in producing them. "Suitable cranes and hoists were not to be found; manufacturers of such equipment would not even co-operate if their old patterns did not suffice." Lien's immediate superior said, "To hell with such policies; go ahead and design your own equipment!" Lien obeyed the injunction. "A former employer of mine fabricated the structures; other independent companies supplied the equipment, all from my detail designs; our own construction men erected the structures and installed the equipment." The completed system proved not only successful but served as a model for subsequent and even more extensive ones.

Lien was now entrusted with organizing and heading the

structural branch of his company's engineering department; he was given the responsibility of designing all new structures for the firm's vast organization. One of his special sidelines involved everything relating to mechanical handling equipment. "Few industries, if any, involve such a variety of requirements for structures, equipment, facilities, and specialties as the power industry does, and the demands made of the planning engineers are of a corresponding nature." The expanding American Gas and Electric Company added many subsidiary units; these frequently had out-of-date steam and hydroelectric generating plants that needed to be converted. Several new super power plants also had to be located and built to serve large united lighting systems. "The various, mostly hidden, engineering problems related to power plant designs must be considered in repeated conferences with other groups of men in the home office and in the field, and they must be coordinated in the designs of the main, more visible structures."

This required considerable travel and afforded broad opportunity for the application of varied skills. It also called for a large staff. Lien states that he "had the opportunity during a period of over ten years (up to the unfortunate depression of the early thirties) to employ many experienced as well as younger Norwegian engineers; in fact, the force consisted mostly of Norwegians." During the depression, when his staff was reduced to two men, he continued to supervise and pass on all designs pertaining to coal and ash handling systems and to contract for all necessary equipment.

Lien, like many another inventive engineer, introduced in rapid succession new ideas and designs that were patentable, but he was unable to exploit most of them. "Most hampering," he writes, "have been the hesitations caused by the cost of patents and the arbitrary, disputable claim or scare that inventions made by an employee belong to the employer whether or not any contract agreement to that effect enters in." Very frequently "the outcome of a good idea is that the manufacturers getting the contracts to furnish equipment according to

certain original designs will use pictures and descriptions of the product as advertising matter and boldly publish the idea as their own, and with slight modifications in some minor detail continue so to use it."

Nevertheless, he did manage to obtain patents on several of his many original ideas. These include three pertaining to screening equipment for coal, ore, gravel, and the like; one for a one-unit automatic coal sampling machine; another for a so-called material accelerator, used to unload solidified granular materials such as coal from railroad cars; and a device to indicate the flow of granular materials, liquids, or gases transported through chutes, pipes or ducts. These and many other devices, together with the dozens of bridges and other structures that he designed for steel, foundry, automobile, chemical, and other industries, and the vast projects undertaken for the American Gas and Electric Company illustrate in an unusual manner the significance of a mechanical engineer in the story of American industrial growth.

ARCHITECTS, SCHOLARS, AND CHEMISTS

CLOSELY associated, both technically and socially, with the engineers from Norway are the architects, though a much smaller group. It would be a mistake to regard them primarily as artists or stylists; often products of one of the Old World technical schools, they might as properly be termed engineers as architects. An able spokesman belonging to their profession has said: "Surely modern architecture should not be the deplorable creation of the would-be style inventors. . . . Since the mound-builders and cave-dwellers, no people, until modern times, ever attempted to adapt a style of a past epoch to the solution of a modern problem. In such attempts is the root of all modern evils."[1] Norwegian architects as a whole would agree with this. In practice they have done honest work along sound structural lines, and their names, generally speaking, are not associated with the eclectic tendencies once so common among their professional colleagues.

I

Perhaps the first Norwegian architect to migrate was Carl Michael Eger, who, says one source, was the son of a royal chamberlain. Eger received his technical education at Düsseldorf in Germany, and obtained his early experience under the then famous Norwegian architect, Nordan, in Christiania. In 1869 he was awarded a government stipend for study abroad. Coming to America, he apparently found life in the New World congenial, for here he remained. His first position in this country was with the Architectural Iron Works of New York,

[1] Thomas Hastings, "Modern Architecture," 98, in Ralph Adams, Thomas Hastings, and Claude Bragdon, *Six Lectures on Architecture* (Art Institute of Chicago, *The Scammon Lectures for 1915* — Chicago, 1917).

and there he made the acquaintance of Niels Poulsen, a far-sighted Dane whose memory is perpetuated in the present American-Scandinavian Foundation. In 1876 Poulsen and Eger founded the Hecla Iron Works, a firm that soon became known for its excellent ornamental iron and bronze products. Eger is credited with the design of the bronze group, "Lioness and Her Young," which was sent to Christiania and placed atop St. Hans's Hill near the city. Throughout Eger's career he displayed energy, shrewd business sense, and a generous nature. When he died in 1916 he left considerable sums of money for an old people's home on Staten Island, and for Our Saviour's Church, the Norwegian Turn Society, and the Norwegian Society, all of Brooklyn.[2]

The early 1880's marked the arrival in America of an architect whose early life in Norway had been somewhat stormy. He was Joakim Mathisen, a native of Trondhjem and a graduate of the Hanover Polytechnicum. At Hanover he had studied under Professor von Haase, an authority on Gothic churches; and upon his return to Norway he took employment with the architect Eilert C. B. Christie. Norway was experiencing at the time what has been termed a "national romantic" movement. In architecture this took the form of a keen interest in the Middle Ages and a movement to restore the national monuments of that period. Christie, himself profoundly influenced by men of the von Haase type, had been charged in 1872 with the stupendous task of restoring the ruins of the cathedral at Trondhjem, succeeding H. E. Schirmer, who had begun the project in 1869.

Mathisen, according to Magnus Bjørndal, became convinced that the restorations of Schirmer and Christie, which were based on German models, were wrong, since the prototype of the Trondhjem structure was the famous Lincoln Cathedral in England. A bitter controversy grew out of the differences between employer and assistant. When Mathisen boldly appealed to the Storting, about twenty of Christiania's architects signed

[2] *Nordisk tidende,* May 18 and 25, 1916; *Nordmands-forbundet,* 9:414 (1916); Rygg, *Norwegians in New York,* 91.

a resolution defending Christie's designs; as a consequence, parliament ignored the appeal of the earnest young architect. Further, we are told, "At least two of the architects, and probably others, of the twenty who signed the resolution had done so under political pressure, in spite of convictions to the contrary, and it is a black page both for the architects and archaeologists of Norway, and not the only one by any means, in connection with the restoration of the Cathedral."

Whatever the merits of Mathisen's case, he was thoroughly discredited in the eyes of his professional brethren and he migrated to America in 1883. In New York he entered the architectural offices of R. H. Robertson and quickly proved himself by designing, during the 1880's, a number of prominent buildings in the East. Later he moved to San Francisco as manager of an office for a New York firm; in 1890 he opened an office of his own there. Known for careful, scholarly work rather than great originality, he enjoyed a wide practice which included several commissions from Japan.[3]

No less interesting and at least equally independent in his ideas was Arne Dehli, who, like Mathisen, received his architectural training in Germany, at the technical schools of Dresden and Stuttgart. While at Stuttgart Dehli came under the influence of such renowned professors and architects as von Leins, Dollinger, and Reinhardt; a group, Magnus Bjørndal informs us, who then rivaled the Vienna school of architects. Returning to Norway, Dehli entered the office of Adolf Schirmer, later state architect, in Christiania; he left for the New World in 1882. In 1885 he, too, entered the office of R. H. Robertson and was later put in charge there.

During his student days, Dehli had studied for some time in Italy. In 1889, with an assistant named G. Howard Chamberlin, he set out on a year's study trip to England, France, and Italy; in 1890 he published the result of his observations in a

[3] Magnus Bjørndal, "Joakim Mathisen," in *Norwegian-American Technical Journal,* vol. 5, no. 1, p. 9 (January, 1932). A more sympathetic picture of Christie and his work is given in the biography of him by Olaf Nordhagen in *Norsk biografisk leksikon,* 3:3–7 (Oslo, 1926).

book entitled *Details of Byzantine Ornament.* In 1894 he published a second work, *Norman Architecture of Palermo and Environs,* which was issued at Boston, London, and Leipzig.

On his return to New York, Dehli opened an office with his friend Chamberlin and quickly built up an extensive architectural practice. From time to time he also published articles on such subjects as fireplace design and various systems of contracting. His professional activity included decorative work with wood, wallpaper, silver, pedestals, furniture, and the like. He also designed, among other structures, St. Jerome's Roman Catholic Church in the Bronx, the Emory Methodist Episcopal Church in Jersey City, the nurses' home for the Norwegian Hospital, and Christ Church in Brooklyn, besides a considerable number of residences. He designed business structures for Glackner's, P. W. Engh's, and the Borden Condensed Milk Company in Manhattan. For the Brooklyn parks department he planned the zoological building in Prospect Park. At first associated with Chamberlin and later with a man named Howard, Dehli practiced alone after 1908. During the First World War he was architect for an export company in New York that did business with the Scandinavian countries. Active in his profession until he died in 1942, he retained throughout his life a keen interest in a variety of subjects, but his greatest enthusiasm was for his own field of work.[4]

Dehli's attitudes may be briefly stated: do good work along conservative lines according to the rules, remembering always that no form is finished, but is in a state of continuous development. He spoke harshly of the eclectics and of those who hold that the Gothic style grew out of certain features found in the Romanesque.[5]

Another early immigrant architect was Kristian Schneider, who came to the United States about 1885 and worked and

[4] The writer was fortunate in having a lengthy interview with Dehli in New York City in May, 1941, and also received considerable information from him through correspondence.

[5] For more information, see Magnus Bjørndal, "Arne Dehli," in *Norwegian-American Technical Journal,* vol. 4, no. 1, p. 12 (April, 1931).

studied under the great Louis Sullivan. Schneider won recognition with his design of the golden arch in the Transport Building at the Columbian Exposition. He was also known for the bronze embellishments on the Carson, Pirie, Scott Building and the decorative work on the Auditorium and the old Schiller and McVicker theaters — all in Chicago. During most of his professional career, which continued until 1935, he was employed by the American Terra Cotta Company.[6]

Olaf M. Topp, a graduate of Trondhjem's Technical College, left for America in 1887. Working at first as an engineer, he soon moved over to the related field of architecture and settled in Pittsburgh. It is as a designer of churches that he is best known. Among the 35 church structures that he planned are the Asbury Methodist Episcopal, Christ's Lutheran, and the Darmont Presbyterian. He also took a keen interest in office and industrial buildings, designing, for example, the Jenkins and Empire buildings and the Jenkins Arcade of the Press Building — all in Pittsburgh.[7]

II

Meanwhile, farther west, Olaf Thorshov was designing many of the best-known structures in Minneapolis. These include the Dayton Company Store and garage, Emmanuel Lutheran Church, Northwestern Hospital, the Walker Art Center, the Yeates Medical Arts Building, the central Y.M.C.A., Minneapolis General Hospital, the Plymouth and Palace buildings, the State Theater, the Radisson, Dyckman, and Curtis hotels, the Strutwear Knitting Company's building, Norway Hall, and the Lavoris Chemical Company's building. He also planned the Concordia College group in St. Paul. Thorshov was born in Norway and was eighteen years old when he migrated in 1901; he began the study of architecture in Minneapolis in 1906. Several years later he entered the architectural firm of Long and Long, which was reincorporated in 1925 under the name Long and Thorshov, with the latter as head of the company. One of the finest examples of Thorshov's work is the Walker Art Center

[6] *Skandinaven*, August 16, 1935.
[7] Alstad, *Trondhjemsteknikernes matrikel*, 66; Wong, *Norske utvandrere*, 156.

on the side of Lowry Hill; it is built in the Venetian-Byzantine style.[8]

Christian Ucherman Bagge was an architect of definitely artistic temperament and inclination; he specialized in making perspective drawings of the many buildings erected during his long association with the D. H. Burnham (later Graham, Anderson, Probst, and White) firm of Chicago. A graduate of the Royal Arts and Handicrafts School, Bagge arrived in Chicago in 1903. It was some time, however, before he discovered the field of his greatest interest—an event that occurred while he was employed by Burnham to make drawings of the famous Chicago Plan. This plan incorporated a number of ideas, commercial and aesthetic, and included arrangements for cutting through Ogden Avenue to Lincoln Park and widening such streets as Roosevelt Road and a part of Michigan Avenue, as well as double-decking Michigan Avenue from Randolph Street north across the Chicago River. Bagge worked almost exclusively with perspective drawings, most of them colored, making sketches of such structures as the Field Museum, the Shedd Aquarium, the Civic Opera House, the Wrigley Building, the Merchandise Mart, and the Union Station. Before his death in 1932 he had acquired a distinguished reputation in his specialized line; he was also locally known for his dislike of our machine civilization.[9]

Erling Owre, whose work has been discussed in connection with the tunnel story, occupies a position similar to Bagge's as architect with the New York City Tunnel Authority. Together with Ole Singstad, Øwre made his start in tunnel work during the construction of the Holland Tunnel.[10]

Ivar Viehe Naess, like Thorshov, received his first technical training in the New World. Coming to Chicago in 1890 at the age of twenty, he attended an evening high school, the local

[8] *Norwegian-American Technical Journal,* vol. 1, no. 3, p. 9 (September, 1928); *Nordmands-forbundet,* 19:518 (1926); Minnesota Federation of Architectural and Engineering Societies, *Bulletin,* 13:29 (July, 1928); Wong, *Norske utvandrere,* 218.

[9] *Norwegian-American Technical Journal,* vol. 6, no. 1, p. 10 (April, 1933); *Skandinaven,* March 1, 1935.

[10] Alstad, *Trondhjemsteknikernes matrikel,* 165; Alstad, *Tillegg,* 46.

art institute, and Armour Institute before returning to Europe in 1897 to study architecture at L'École Nationale des Beaux Arts in Paris. D. H. Burnham had seen evidences of some of Viehe Naess's work in the Chicago Trust and Savings Bank, done no doubt when he had designed interiors and furniture for the A. H. Andrews Company; and in 1900 he asked Viehe Naess to join his company. Burnham at that time was beginning to work on bank buildings. Viehe Naess remained with Burnham until 1912; during the last six years he served as chief draftsman and had an important part in planning many of the principal banks and office buildings in the country. In 1913 he began his own practice in Chicago and thus continued to figure in one of the greatest building epidemics in American history. Banks, office buildings, churches, hospitals, and other institutional structures followed close on one another. Among the buildings that he designed were the Home National Bank in Arkansas City, Kansas; the Norwegian-Lutheran Deaconess Hospital in Chicago; the Elmhurst Hospital; and the South Chicago Savings Bank Building. In 1924 he won a gold medal for designing and constructing the best Chicago building of the year — an office structure for the Standard Corporation on East Superior Street.[11]

Viehe Naess also had charge of the architectural planning, under the direction of Graham, Anderson, Probst, and White, of the Chicago Civic Opera House; he thus helped to transform a site along Wacker Drive covered by old buildings and docks into a beauty spot supporting a modern French Renaissance structure of 45 stories.[12]

III

It may be true, as one writer has said, that "the mission of the moving-picture theatre is to vulgarize America"; certainly it is a fact that in the development of the movie house "Architecture was seized upon and dragged into the arena to make the

[11] *Norwegian-American Technical Journal,* vol. 2, no. 1, p. 11 (March, 1929); materials in the archives of the Norwegian-American Technical Society, Chicago.

[12] See Viehe Naess's able analysis of this building in *Norwegian-American Technical Journal,* vol. 3, no. 1, p. 1, 12–14 (February, 1930).

Roman holiday complete."[13] But the movie is now a recognized part of American life and the movie house an architectural feature of loop district, suburb, and village everywhere. In the growth of this machine-age theater a more than incidental part was played by S. E. Sonnichsen. Sonnichsen attended the Royal Arts and Handicrafts School in Christiania and the Baugewerk School at Eckernførde in Schleswig-Holstein, graduating as an architect in 1902. Leaving in the same year for America, he drifted from job to job in New York, Chicago, Denver, Cheyenne, and Seattle. It was in Seattle, serving as chief draftsman for W. M. Somerwell and Company, that Sonnichsen began to work as an architect. When the company moved to Vancouver in 1911, he accompanied it and took part in designing churches, schools, hospitals, libraries, and private homes. Returning to Seattle in 1918, he opened his own architectural firm, and did an extensive business.

In Seattle Sonnichsen was architect of beautiful Norway Hall. This building, it might be remarked, contains several paintings by Sonnichsen's brother, Yngvar, that depict scenes from the Viking age. The structure itself was built of wood in the Norwegian *bonde* tradition.[14] Sonnichsen also designed and built plants for machinery companies and foundries, fish canneries in Alaska, smokeries for the Pacific Alaska Cannery Company, railroad piers for the Canadian Pacific Railway, warehouses for the Pacific Fruit and Vegetable Corporation, wharves and piers of all kinds, a hospital, a power plant, and a baseball grandstand. He was ready not only for a rest but also for a specialized line of work when he went to California in 1923.

When he arrived there he became acquainted with B. Marcus Pretica, a well-known theater architect of Los Angeles, and formed a partnership with him. Since then Sonnichsen's work has been the design and construction of movie palaces. Sonnichsen was superintendent of construction for the Pantages Theater and office building in San Francisco and had charge of plans

[13] Tallmadge, *Architecture in America*, 283.

[14] "Norway Hall in Seattle," in *American-Scandinavian Review*, 10:430 (July, 1922).

and specifications, supervision, contracts, and general office management for the Pantages Theater in Los Angeles during 1925–26. Then he built the Pantages theaters at Hollywood and Fresno and the Warner Brothers theaters in San Pedro, Huntington Park, and Beverly Hills. While Pretica and Sonnichsen have been hailed as leaders in west coast theatrical architecture, their work has included industrial plants, office buildings, and apartments. During Sonnichsen's association with Pretica, the firm's Los Angeles office was entirely under Sonnichsen's personal direction, and he was responsible not only for office management but also for plans and designs.

Sonnichsen, asked to discuss the architecture of the movie house, replied that he has always been a "firm believer in the theory that form follows function" and that he has "endeavored to adhere to this principle as diligently as possible, avoiding false fronts and the misuse of materials, observing the duty of an architect with due respect to his client and the public at large." He has tried "to produce a proper functional plan—correlating therewith all requirements for proper seating, acoustics, ventilation, etc., and careful observance of public safety regulations as well as thought for the patron's comfort. The decorations have been incorporated as an integral part of the building to form a suitable frame or setting for the presentations; in the motion picture house this should be kept simple, leaving the screen to tell its story without distraction from surrounding sources."[15]

IV

Amund Fjørtoft, architect with Shaw, Naess, and Murphy of Chicago, is known for his work in the design and construction of hospitals. For some time he was chief designer in the Cook County architect's office and there supervised all designs of the large Cook County Hospital. He was recently chief designer in the construction of our army and air base in Bermuda. The

[15] Letter to the present writer, March 29, 1941; for sketches of Sonnichsen, see Johan Selnes, "En telemarksgutt i California," in *Nordmanns-forbundet,* 25:146–148 (May, 1932); and *Jarlsberg og Larviks Amtstidende* (Norway), January 21, 1932. Sonnichsen furnished considerable additional material.

contracts called for barracks, hospitals, schools, officers' houses, and recreational and sports facilities.[16]

On the roster of Norwegian architects in America are also the names of D. C. Ottesen, a graduate of Trondhjem's Technical College, who designed many of Milwaukee's largest buildings and served as superintendent of school buildings and grounds in the same city; Ole Aga, who spent only a part of his interesting life in America but played a leading role in planning the Cook County Hospital; and John A. Gade — born in America, brought up in Norway, and educated at Harvard — who designed, among other buildings, the Rochester (New York) Memorial Art Gallery and several Norwegian Lutheran churches.[17]

The list includes, too, such men as O. I. Tolaas, graduate of Trondhjem's Technical College, who became chief architect for the Northern Pacific Railway Company at St. Paul in 1909; and O. M. Rognan, largely self-taught, who succeeded Tolaas in 1917 and continued the designing of shops, stations, and roundhouses. William L. Finne, a graduate of the Royal Arts and Handicrafts School of Christiania, designed a number of skyscrapers in New Jersey, including the N. J. Levy Building in Newark, and gained a reputation for general architectural work in and about Elizabeth, New Jersey, where his firm has its office.[18] Harold Hals, a product of the institutes at Charlottenburg and Stockholm, had a part in the planning of the La Salle Hotel, the Brandeis Theater, and the county courthouse in Chicago before returning to Norway in 1911.

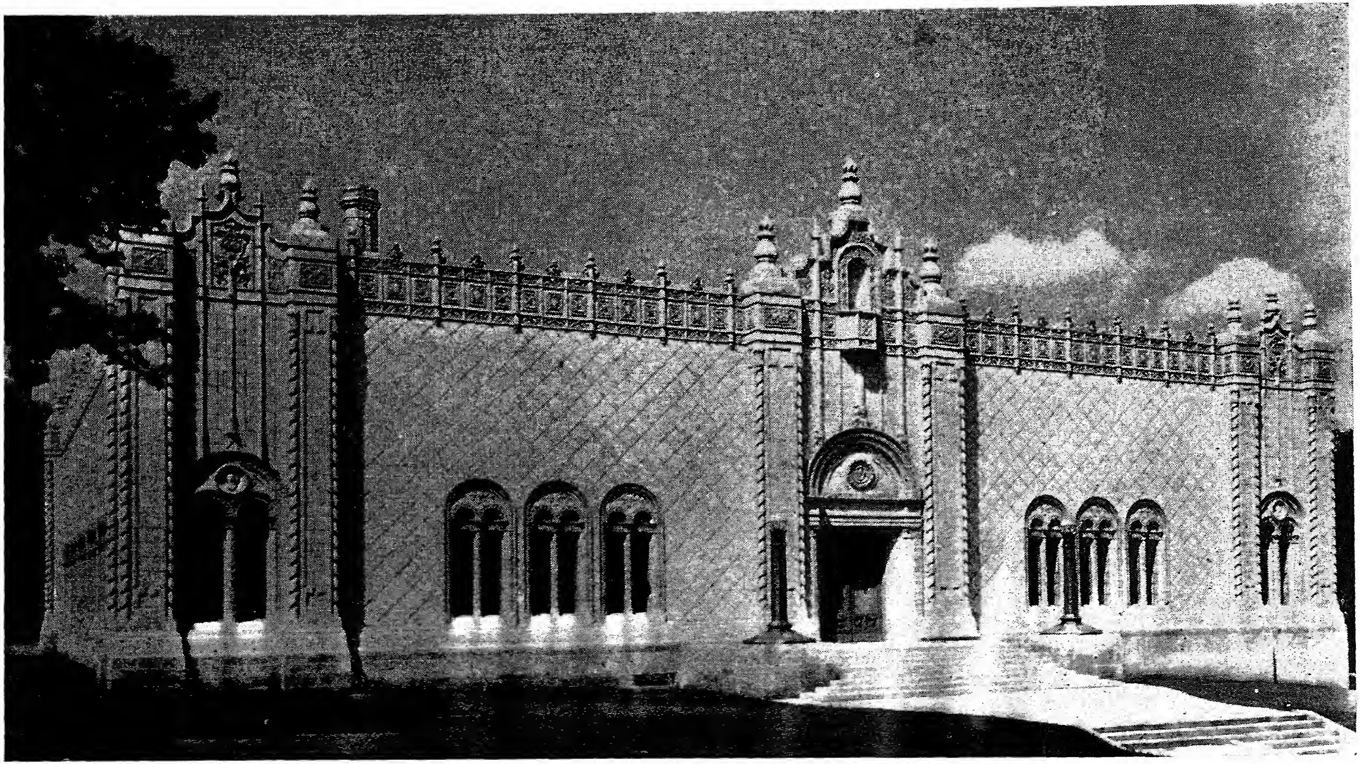
Our account is incomplete without mention of Carl Volkman of Eau Claire, Wisconsin, a graduate of the Royal Arts and Handicrafts School. He was the designer of numerous buildings in North Dakota, Saskatchewan, and Wisconsin, including the Scandinavian-American Fraternity Building in Eau Claire. Si-

[16] H. Sundby-Hansen, in *Nordisk tidende*, October 23, 1941.

[17] Alstad, *Trondhjemsteknikernes matrikel*, 8; Alstad, *Tillegg*, 14; *Nordisk tidende*, March 14, 1929; *Nordmands-forbundet*, 5:357–366 (1912), 9:544–549 (1916), and 22:325 (1929). See Gade's *All My Born Days; Experiences of a Naval Intelligence Officer in Europe* (New York, 1942).

[18] *Nordisk tidende*, August 27, 1925.

The Chicago Opera House: Twenty Wacker Drive



The Walker Art Center (ORIGINAL FRONT)

gurd Rognstad of Chicago put up the city hall in Chinatown and a large building in Garfield Park. Brynjulf Revenes of Glendive and Miles City, Montana, planned many of the leading structures in that state. Odd Nansen, son of the famous explorer-humanitarian, recently won recognition in connection with the design of an airport.[19] Engebret Sund built a number of Twin City structures, including Central Lutheran Church in Minneapolis.

It is reasonable, when one considers the close relationship between Norwegian immigration and Mormonism, to find that one of the leading architects among the Latter-day Saints is of Norwegian birth and training. Ramm Hansen, a student of the Royal Arts and Handicrafts School, was converted to the Mormon faith during his school years and went to Salt Lake City in 1901. After working for other architects there, he entered into a partnership in 1916 with a descendant of Brigham Young. The firm Young and Hansen designed and built the Mormon Church Offices Building and the Federal Reserve Bank Building in Salt Lake City, the temple at Mesa, Arizona, and the Mormon Church — constructed of Utah marble — in Washington, D.C. Recently the firm was engaged in building two new temples — one at Idaho Falls, Idaho, and the other at Westwood, in Los Angeles. Young and Hansen also planned the Central Building at the University of Utah.[20]

V

Many of the architects who have been mentioned turned at one time or another to designing residences. Birger Kvenild of Omaha has specialized in this field. After his graduation from Trondhjem's Technical College in 1901, travel and study in Germany, France, and England provided Kvenild with a background peculiarly well suited to his work for monied clients in Nebraska. A meat packer, upon returning from a vacation trip

[19] Materials in the archives of the Norwegian-American Technical Society, Chicago; *Skandinaven,* November 19, 1937; *Yellowstone Journal* (Miles City, Montana), December 26, 1919; *Nordmands-forbundet,* 23:58 (1930).

[20] Interview with Hansen, August, 1940.

in Europe, might call upon Kvenild for a Norman chateau or a Sussex country house, and see his wish fulfilled. Omaha is dotted with superb examples of Kvenild's art. Frankly eclectic, he regards the architect as an artist-craftsman who should supervise every detail of construction, including the engineering and contracting aspects. Though he has given his time almost exclusively to dwellings since 1918, Kvenild was also secretary and architect for the Omaha Planning Commission and thus was largely responsible for the city's present new streets, boulevards, and other developments that were an outgrowth of the commission's proposals. Maintaining offices in his own home, Kvenild, in his attitude toward both his work and the people he works for, resembles no one so much as an artist of the Italian Renaissance, and no one is more contemptuous than he of men posing as architects whose training and abilities fall short of his ideal of versatility.[21]

Elias Wessel Klausen, who in several respects resembles Birger Kvenild, belongs to a younger generation of architects. A graduate of the Institute of Technology at Trondhjem, Klausen was once associated with the M.G.M. Studios in Hollywood and with Wallace Neft of Pasadena, a prominent residential architect of southern California. Klausen later won national recognition for his designs while working for Virgil Westbrook in San Clemente, and in 1930 he established a firm of his own which specializes in residences. He has built many houses in San Clemente, Westwood, and Brentwood Heights, all of them characterized by honesty, simplicity, and good taste in design.[22]

VI

The dividing line between architect and artist is no more distinct than that between architect and engineer. A number of engineers or architects have in fact devoted their major efforts to the fine arts. Yngvar Sonnichsen, representative of this group, graduated as a civil engineer from Trondhjem's Technical Col-

[21] Alstad, *Trondhjemsteknikernes matrikel,* 170; Alstad, *Tillegg,* 47; interviews with Kvenild in June, 1940.

[22] *Pacific Coast Viking* (Los Angeles), May, 1939; information supplied by Klausen.

lege, then took instruction in the fine arts at the Royal Arts and Handicrafts School in Christiania, the royal academies of Antwerp and Brussels, and the Académie Julian at Paris. He was particularly interested in the craftsmanship of the early Flemish painters. Sonnichsen practiced his painting art for a time in Norway and exhibited at Christiania, then moved to Canada in 1904 and opened a studio in St. John, New Brunswick. There he specialized in art glass windows for churches and did a portrait of Thorwald Christensen, former chamberlain to King Oscar I of Sweden. Sonnichsen moved to Seattle a few years later and there did a number of portraits and some landscapes depicting the orchards and farmlands of eastern Washington. Traveling to Alaska, he painted scenes from the rugged southeastern portion of the territory. Mention has been made of his work, together with that of his architect brother, in Seattle's Norway Hall, where the murals were done by Sonnichsen and Sverre Mack, a Norwegian artist. These murals depict mythological and historical scenes in harmony with the *bonde* style of wooden building. Some of Sonnichsen's principal portraits are those of Ole Bull, Edvard Grieg, and Roald Amundsen. In 1933–34 he was engaged by the Civil Works Administration to paint landscapes for the Seattle public schools.[23]

E. O. Drogseth, too, studied architecture and painting in Christiania, Paris, and London before leaving for America in 1907. Though he practiced architecture for a time, he was soon at work making paintings of skyscrapers in Cleveland and Detroit, and ultimately he devoted his energies exclusively to painting, in which field he won a fair reputation. His paintings may be found in the Pennsylvania Academy of Fine Arts and in a number of private collections. For many years he maintained a studio at Bear Lodge, Bearsville, New York, living there during the greater part of each year.[24]

The Norwegian engineers and architects also claim as one of their group Henry O. Jaastad; but while he was born in

[23] Johan Selnes, in *Nordmands-forbundet,* 22: 237–239 (1929); *Who's Who in America,* 20: 2327 (Chicago, 1938–39).
[24] Wong, *Norske utvandrere,* 81.

Norway, Jaastad has spent most of his life in America and he received his architectural training at the University of Arizona. Now a leading architect in Tucson, he is chiefly interested in Spanish missions and the native Indian architecture. Jaastad has been called the leading authority on the missions of Arizona, having made exhaustive studies of this subject both in his own state and in Sonora, Mexico. Among the buildings that he has designed are churches, schoolhouses, and Y.M.C.A. structures; the schools include the Navajo Indian School at Ganado, Arizona, and the Menaul School for Mexican boys at Albuquerque, New Mexico. According to one writer, among Jaastad's best creations are "the small churches which one comes across in several of the southern Arizona towns; all are charming and usually follow the Spanish mission style." The Safford School, at Tucson, is one of his most ambitious works; it gave him "an opportunity to create on a large scale something absolutely true to Arizona and based on its historic monuments." The commentator continues: "It should be known that the Spanish Missions of Arizona are of a style quite their own in that they seem to partake more of the Moorish influence than is usual in mission architecture. It was this individual character which Mr. Jaastad kept in mind when developing the design for the Safford School. . . . [He] is to be commended upon his breaking away from the commonplace and recognizing the architectural traditions of his field."[25]

VII

Some of the Norwegian engineers were drawn into the academic fields, both in America and Norway; they were attracted as much by the opportunity to engage in research as by the impulse to impart knowledge.

One of the earliest of the group to teach in an American institution was Storm Bull, a graduate of the Polytechnic Institute at Zurich, who became an instructor in mechanical engineering at the University of Wisconsin in 1879. Rapidly

[25] Prentice Duell, in *Western Architect,* quoted in *Norwegian-American Technical Journal,* vol. 1, no. 2, p. 5 (May, 1928).

promoted, he was professor of steam engineering in 1886. Besides engaging in research and writing many scientific papers, Bull was on the jury of awards at the Paris Exposition in 1900, served as vice-president of the Society for the Promotion of Engineering Education, 1901–02, and was winner in 1903 of the Chanute medal of the Western Society of Engineers. He was also consulting engineer for the Wisconsin state capitol commission and the university board of regents, to mention only two of his varied services.[26]

One of the most prolific writers among the engineers was Peder Lobben, who began his technical career as an apprentice in the Kongsberg gun factory and left for America in 1879 to take employment in the gun factory of Johnson, Bye, and Company at Worcester, Massachusetts. Lobben returned shortly to Norway, studied for a time at Horten, and again set out for Worcester. He completed a correspondence course in engineering offered by the International Correspondence Schools of Scranton, Pennsylvania, and became director of plants for his firm. Again returning to Norway, he summed up some of his technical experiences and theoretical studies in such books as *Lommebog for mekanikere* (Pocketbook for Mechanics) and *Elektricitet og magnetisme* (Electricity and Magnetism). In 1900 he also published, in America, the first edition of his *Machinists' and Draftsmen's Handbook.* These books were extensively used because of their helpful tables, detailed accounts of machines, and clear discussion of common problems.

Back in America in 1902, Lobben became director of Dr. Thaddeus Cahill's electric laboratory at Holyoke, Massachusetts. Cahill, an inventor, was at the time working on electrically-produced music. Lobben remained with him until 1911, when he became technical head of the Andersen Manufacturing Company in Boston. In 1913 he returned to Norway to remain, and several years later opened a correspondence school in Christiania which offered courses in mathematics, mechanics, and electrotechnology; he himself wrote the neces-

[26] American Society of Mechanical Engineers, *Transactions,* 29:1173 (1907).

sary texts. During this period in the homeland he put out new editions of the *Lommebog, Elektricitet og magnetisme*; in addition he published, in 1915, *Elektriske vekselstrømme* (Electric Alternating Currents) and then, in 1917, *Induktionsmotorer og transformatorer* (Induction Motors and Transformers). Many machinists and electricians as well as students and engineers, both in Europe and America, have benefited by Lobben's writings.[27]

Dr. Magnus C. Ihlseng is generally regarded as one of the Norwegian engineer group, despite the fact that he received all his technical training at the Brooklyn Polytechnic Preparatory School and Columbia University; at the latter institution he was awarded the Ph.D. degree in 1878. Before and after receiving the advanced degree he served as instructor in physics at Columbia, leaving in 1881 to become professor of mining engineering at the Colorado State School of Mines at Golden. In 1893 he was appointed dean of the school of mines in Pennsylvania State College, and in 1889 he became professor of mechanical engineering at the Brooklyn Polytechnic Institute. He held the latter position only until 1906, but continued his association with the school until his death in 1930. In 1906 he became examining engineer for the New York municipal civil service, a position that he held until his death. For half a century he was consulting engineer for location, examination, and the development of mining properties in the American West, Mexico, South America, and Cuba, and in the coal fields of Illinois, Pennsylvania, and West Virginia. He was the author of a standard *Manual of Mining* (1896) and of numerous articles published in technical journals, including "A New Method of Determining the Velocity of Sound and Modulous of Electricity," read before the National Academy of Sciences. He is also credited with the invention of a widely used slide rule for chemical computations and with notable contributions in such fields of investigation as the coefficient of elasticity in

[27] *Nordmands-forbundet,* 14: 384–388 (1921); *75 års biografisk jubileums-festskrift, Hortens tekniske skole,* 138.

metals, the velocity of sound through woods, and the treatment of ores.[28]

While it is not the intention of this study to enumerate all of the engineers in the teaching field, mention may be made of A. S. Riddervold, a graduate of Christiania's Technical College, who was associate professor of civil engineering at the University of Nebraska, 1911–18; Aksel Andersen, who returned to Norway in the late 1930's to become professor of statics and bridge engineering at the Institute of Technology in Trondhjem; and Inge M. Lyse, who also recently became a professor at Trondhjem following a brilliant career with building materials in America.

Several Norwegians have established schools in this country for navigators, machinists, and the like. Typical of this group was Ingvald Tonning, who organized a school of marine engineering in New York in 1914 after an unsuccessful attempt at founding an American-Scandinavian technical school. By 1922 he was credited with having turned out between 1,400 and 1,500 marine machinists of all national origins, most of them Scandinavian. After 1920 he had as a partner in his school J. C. Reid, a mechanical engineer. Tonning continued his association with the school until his death in 1932.[29]

VIII

In the field of theology P. G. Zwilgmeyer, a graduate of Bergen's Technical College and an engineer in the right-of-way department of the Northern Pacific's western headquarters, has been a prominent writer for the Norwegian-American church press. His "Bibelkritik" (Biblical Criticism), which was printed in eight installments of *Lutheraneren* in 1911 and 1912, is of more than casual interest, as is also his study of "Luther som menneske og reformator" (Luther as Man and Reformer), which appeared in twenty parts in the same periodical, 1914–15. Zwilgmeyer has also written articles on theological and scien-

[28] *Nordisk tidende,* December 8, 1921; *Norwegian-American Technical Journal,* vol. 4, no. 1, p. 14 (April, 1931); *Who's Who in America,* 4:916 (Chicago, 1906–07).
[29] *Nordisk tidende,* April 20, 1922.

tific subjects for *Teologisk tidsskrift* (Minneapolis) and on engineering subjects for such journals as *Professional Engineer* and *Pacific Engineer*.[30] These writings consistently reveal the mind of a keen and patient scholar.

Not all the engineers who have interest in theology have remained within the Lutheran fold; some, in fact, have strayed far afield. Olaf Bastesen, structural designer and draftsman for the Carnegie-Illinois Steel Corporation at Gary, was first a member of the American Theosophical Society and for a time president of the Annie Besant lodge in Chicago. Then he joined the Liberal Catholic church and eventually became absorbed in theological studies. He accepted orders in the Liberal Catholic church and is now an ordained priest. For four years he was in charge of St. Alban's Church and is now an associate priest at the Church of St. Francis in Chicago.[31]

Nor is the group without a gospel singer. Eivin Bjørnstad, one of the foremost gospel singers of the country, originally studied engineering in Munich and during that time discovered his unusual voice. Trained by such teachers as Elfret Florio and Oscar Saenger, he made his opera debut in New York but returned to sing in the cities of Europe. While performing in opera he became deeply religious, and has since devoted his considerable talent to interpreting the simple gospel songs. Frequently he sings to full houses in Chicago's new Civic Opera House or the enormous Moody Memorial; nor is it unusual for him to sing before packed audiences in the Moore Theater in Seattle for a solid week.[32]

IX

One is strongly impressed by the assurances of many Norwegian engineers in executive positions that they have never had labor trouble in their plants. These men are usually quick

[30] *Nordmands-forbundet*, 18:275 (1925); archives of the Norwegian-American Technical Society, Chicago; information supplied by Zwilgmeyer. See Zwilgmeyer's able study of "Blaise Pascal," in *Teologisk tidsskrift* (Minneapolis), 6:241–268 (July, 1923).

[31] Information obtained from Bastesen.

[32] An interesting article about Bjørnstad appeared in the July 28, 1938, issue of *Nordisk tidende*.

to add, sometimes knocking on wood, that of course they might not be so fortunate in the future. With some exceptions, the Norwegian engineer is peculiarly qualified for leadership because of his ability to comprehend another's point of view, and he possesses what is equally important, a sympathetic understanding of poverty and insecurity. These characteristics are due in part to his alliance with an immigrant group that has itself experienced insecurity; the engineer himself is very likely to have worked as a common laborer, and he knows the mind of the working class. No attempt will be made at this point to deal specifically with the social philosophy of the engineers, but the conduct and views of two men are presented as illustrating in a peculiarly effective way the outlook of many of the group.

Hans O. Egeberg took the *artium* examination in Norway in 1895, and studied at the Dresden Polytechnicum for two years. He came to America in 1897, and completed his technical education at Cornell University. From the time of his graduation in 1900 until his death Egeberg was employed in the steel industry, first in Chicago, then at Gary. Though his technical career included the supervision of construction, in Pittsburgh, of the machinery destined for the Gary steel mills, his real life work began when he was made superintendent of labor. Egeberg's knowledge of the immigrant and his problems and his kindly interest in the men under his direction soon made him both friend and adviser to some sixty or seventy thousand employees — mostly South Europeans and Mexicans. His problems multiplied in the early 1930's, when lowered wages and unemployment caused great unrest, but his helpfulness and generosity were unfailing. According to *Nordmanns-forbundet*, "He had the rare faculty of being able to mingle with people of all classes. He was just as often on the workers' side as on the side of the steel trust, and because he was incorruptible and just, the workers looked up to him as to Providence itself." When Egeberg died in September, 1933, the steel company arranged a public funeral. His body lay for two days in the city's largest

church and thousands passed by his coffin for a last look at their friend and benefactor.[33]

The other man who distinguished himself in labor relations is Alfred Vaksdal, plant engineer of the Corning Glass Works, where he is in charge of the powerhouse, machine shops, and other mechanical service divisions. Vaksdal has expressed himself clearly and vigorously on the subject of dealing with workers — a task, incidentally, that he considers the most difficult of all problems. Human engineering, as he calls it, demands of the leader kindness, truthfulness, competence, and — above all — a keen sense of justice. The best way to maintain a healthy relationship is to be thoroughly human, to mingle with the men. "The manager who thinks he can lead his men from his office by charts and curves, pushbuttons, telephones and autocalls, like the engineer who is synchronizing machines he does not see, is badly mistaken." In summing up his comments on the subject of maintenance, Vaksdal shrewdly observes, "When everybody is planning for better service and effort is wisely directed with justice and kindness, men will be happy and will give you their best with the greatest possible safety."[34]

X

Chemical engineering has promise of a particularly bright future, and the material side of the engineer story should conclude with a brief discussion of some of the chemists who in the past have contributed to America's growth. Their work in the fields of metallurgy and wood derivatives has already been discussed; what remains to be told is no less significant.

In the field of chemical dyeing, we come upon the name of Olav Berg, a product of the Bergen and Dresden schools. Berg came to America in 1906, became associated with Dr. Max Imhoff in 1912, and with him founded the Imhoff-Berg Silk Dyeing Company. This firm soon occupied a prominent position in the

[33] *Nordmanns-forbundet,* 26:357 (1933); *Skandinaven,* September 29, 1933.
[34] Vaksdal, "Keep Human!" in *Power,* 83:79 (March, 1939); Vaksdal, "The Success of Production Is Tied to Maintenance," in *Factory Management and Maintenance,* 97:88 (June, 1939).

industrial life of Paterson, New Jersey; and Berg became a well-known chemical authority as well as an inventor of apparatus used in silk production. Before his death in 1934 his company had progressed to become the Phoenix Piece Dye works and the Berg Silk Dyeing Company.[35]

In the chemical line as in other branches of engineering there are self-taught leaders. William N. D. Rohde was a specialist in ink. His long and productive association with the Sanford Ink Company began in 1880. Becoming interested in the composition of his firm's product, he began the study of chemistry; thereafter he climbed rapidly until he became head of the chemistry department. In 1935 Rohde could look back on fifty-five years of service, during which time 10,000,000 gallons of ink was produced by Sanford, most of it under his technical direction.[36]

The recent death of Dr. Fin Sparre, a director and for a quarter-century head of the development department of E. I. Du Pont de Nemours and Company, brought to a close the career of the leading Norwegian engineer in the field of explosives. A graduate of Christiania's Technical College, Sparre also studied at Dresden and for a short time worked in Germany. Returning to Norway, he was employed at Gjøvik in the manufacture of ammunition for the Norwegian army. In 1903 he accepted a position as chemist with the Du Pont Company at Wilmington.

At that time, Du Pont was exclusively interested in the production of explosives, but in the years that followed the firm branched out into other activities. In this expansion Sparre figured prominently, becoming chief chemist and in 1912 director of the experimental station at Wilmington. During the First World War he traveled to England, France, and Norway on a mission undertaken jointly by the army ordnance department and the Du Pont firm, to study the chemical aspects of war production. In 1918 he was named assistant director of

[35] *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 21 (November, 1935); *Nordisk tidende,* April 14, 1921; *Scandia,* December 20, 1934.

[36] *Skandinaven,* August 23, 1935.

Du Pont's development department and in the following year became its director. Sparre was elected a director of the firm in 1930 and three years later he achieved a similar position with Remington Arms Company at Bridgeport, Connecticut. He served on the National Inventors Council and on an advisory committee on patents named by the Secretary of Commerce. After 1942 he was also a member of a committee advisory to Major General L. H. Campbell, Jr., chief of ordnance.

Though it was Sparre's interest in explosives that brought him to America, he was entirely connected with industrial expansions during his forty-one-year period of service with Du Pont. He lists no inventions or new processes, but the wide scope of his technical activity is shown in the fact that he not only headed the development department but also served as director of the Du Pont Cellophane Company, the Du Pont Rayon Company, the Du Pont Ammonia Corporation, and the Rossler and Haslacher Chemical Company.

A merciless spotlight is now focused on the exchange of technical secrets by international cartels. In 1934, when discussion centered about the exchange of military information between the United States and Great Britain—with particular reference to TNT and the manufacture of "tetrol"—and Du Pont officials announced that their company had never given a military secret to a foreign country except during the First World War, Sparre chided the investigating committee of the Senate by saying that all formulas patented by Du Pont people could be purchased for ten cents by securing a copy of the patent office *Official Gazette*. He also revealed that Americans first learned how to produce TNT through information which was seized from the Germans during World War I and passed on to us by the British.[37]

The application of chemistry to war is usually a positive or destructive one. A recent news item, however, announces a new

[37] I.N.S. news item from Washington, D. C., December 7, 1934. Information about Sparre's career was found in an article by Magnus Bjørndal in *Norwegian-American Technical Journal*, vol. 5, no. 1, p. 6, 9 (January, 1932); *Nordisk tidende*, October 12, 1944; *New York Herald Tribune*, October 8, 1944; material supplied by Dr. Sparre.

substance, deoxolin, which "may rob the incendiary bomb of its menace by flameproofing buildings and clothing." This liquid, which was made available to the United Nations, is the discovery of Dr. O. T. Hodenfield, a Norwegian-born chemist, and it is, we are told, being manufactured in large quantities.[38]

With the growth of motor transportation in the present century, petroleum has assumed an obvious importance, and quite naturally a number of Norwegian engineers have given their time and energy to research connected with it. Several, all of them graduates of the Norwegian Institute of Technology, have made lasting contributions in the chemistry of oil.

Johannes H. Bruun, manager of the experimental division of the Sun Oil Company at Norwood, Pennsylvania, received his early education in Finland, where his father served as consul; after a year's technical training at the Finnish Institute of Technology, he completed the chemical course at Trondhjem in 1923. Bruun left for the New World in 1924, intending to acquire experience as a laborer in the American pulp and paper industry, preparatory to a technical career in the same field in Norway. He found employment with the American Aniline Products, Inc., at Lock Haven, Pennsylvania, and became superintendent of manufacture in several plants. Switching to the national bureau of standards in 1927, he became senior research associate of the American Petroleum Institute within the bureau. In 1933 Bruun transferred to the Sun Oil Company of Philadelphia and two years later was made manager of its experimental division. Author of numerous articles in the *Journal of Research* issued by the bureau of standards, and in *Industrial and Engineering Chemistry* (1929–39), he was also the inventor of the "Bruun column," a laboratory distillation device. He began, among other research programs, Project Number 6 of the American Petroleum Institute, developing, with others, new methods of separating the constituents of petroleum. This project still continues as America's most impor-

[38] *New York Herald Tribune,* April 19, 1942.

tant research undertaking in petroleum. Bruun found it possible during a busy career to earn a Ph.D. in chemistry at Johns Hopkins University (1929); and in the years between 1928 and 1936 he visited many universities and research laboratories in Germany, France, England, Italy, Holland, Switzerland, and Belgium.[39]

One of the leading industrial chemists of America is Dr. Per K. Frolich, director since 1936 of the Esso Laboratories, chemical division, of the Standard Oil Development Company, and president, in 1943, of the American Chemical Society. Frolich completed his course in electrochemistry at the Norwegian Institute of Technology in 1921 and served for two years as an assistant in chemistry. Accepting a fellowship from the American-Scandinavian Foundation, he enrolled for postgraduate work at the Massachusetts Institute of Technology, where he received the degrees of master of science and doctor of science in 1923 and 1925. At M.I.T. he was also a research assistant, research associate, and, from 1927 to 1929, associate professor of chemical engineering, as well as assistant director of the research laboratory of applied chemistry. During what might be called his academic period, from 1922 to 1930, Frolich published no less than thirty research papers dealing with such subjects as high-pressure synthesis and the part played by catalysts in high-pressure reactions, and covering the general field of electrochemistry. In 1930 his work on gas reactions under high pressure earned for him the Grasselli medal of the Society of Chemical Industry.

Transferring in 1929 to the industrial field, toward which his interests naturally led him, Frolich joined the research staff of the Standard Oil Development Company. In 1931 he was promoted to assistant director of the research laboratories, and by 1933 he had become director. Because of the widening scope of the work of the development company, its chemical and oil research activities were brought under a separate division in

[39] Archives of the Norwegian-American Technical Society, Chicago; and information received from Dr. Bruun.

1935, and Frolich was named chief chemist. One year later he was director of the newly created chemical division of the Esso Laboratories. Since 1930 he has published extensively the results of research in which he has been engaged, bringing the total of his scientific papers to well over fifty. In addition, he holds as many patents dealing with petroleum processes and products. Frolich may thus be said to occupy a position in the very heart and nerve center of research in the all-important petroleum industry.

No one is better qualified than Frolich to discuss the important question of "Petroleum, Past, Present, and Future," which was the subject of his presidential address delivered before the 106th general meeting of the American Chemical Society at Pittsburgh in 1943. Frolich optimistically stated that not only are there large undiscovered reserves of petroleum in the United States and elsewhere, but also a considerable unused volume is known to be in the ground. He did not attempt to predict how soon the total supply would be exhausted, but he assured his listeners that there was little reason to look for a sudden change in the availability or use of such products as gasoline. Progress is being made steadily in the efficiency of processing methods and the quality of petroleum derivatives, and improved engines are resulting in improved utilization of both fuels and lubricants. At the same time increased drilling is adding to the available supply of petroleum. Sooner or later, of course, a shortage of natural oil will occur, but synthetic products will appear on the market so gradually that the consumer will hardly be conscious of the transition that has been made possible by science.[40]

The chemical work of the development company under Frolich's direction has expanded greatly; and research has focused on lube oil additives, the chemical utilization of refinery gases, high-pressure oxidation, and the synthesis of low and high molecular weight polymers from petroleum gases. But of more

[40] Per K. Frolich, "Petroleum, Past, Present, and Future," in *Industrial and Engineering Chemistry,* 35: 1131–1138 (November, 1943).

interest is the work in the field of synthetic rubber. Research on synthetic rubber raw materials and synthetic rubber derived from petroleum by-products had proceeded leisurely before 1941. It was America's entrance into World War II that dramatized the struggle to provide substitutes for the natural rubber supplies which were cut off by the Japanese. Even before the disaster at Pearl Harbor, Frolich predicted that because of the extensive work already done in applying synthetics to special uses and the familiarity thus acquired with methods of processing rubbers, wise planning would enable American chemists to expand the output of synthetic rubber to meet domestic needs as well as military in time of emergency. The great contribution of the chemical division, headed by Frolich, lay in the development of butyl rubber, which was extensively used in the war effort; improvement in the methods of producing butadiene and other synthetic rubber raw materials; and in making available to other industries the information necessary in the production of buna rubber. Dr. Frolich, like many good scientists, is as modest as he is energetic and he insists that credit for the work with which he is associated "should go to the organization of which I am the head, rather than to me as an individual."[41]

Hans Gudbrand Vesterdal, also a graduate of the Norwegian Institute of Technology, is a research chemist with the Standard Oil Development Company, and a long list of patents in his name attests to significant research in the improvement of petroleum products. Thorleif Ellison, who completed his technical education at Christiania's Technical College in 1924, served for a time with Standard Oil and more recently as designing engineer with the Solvay Process Company of Hopewell, Virginia. In charge of mosquito extermination with the board of health in Brooklyn, 1934–35, he was able to effect a great

[41] *Chicago Tribune,* December 13, 1940; report of an address delivered by Frolich before the opening session of the National Industrial Chemical Conference at Chicago. The writer is indebted to Frolich for considerable information and for many items appearing in the *Chemical and Engineering News* and *Industrial and Engineering Chemistry.*

reduction in the insect nuisance. Karl Theodor Nilsson is a chemical engineer for the Solvay Process Company at Syracuse, New York; he is a graduate of the Norwegian Institute of Technology and also holds an M.S. degree from the Massachusetts Institute of Technology. These and many others are demonstrating that in the relatively new field of chemical engineering the record of the graduates of Norway's schools will one day look as impressive as that of the earlier engineers in mechanical, structural, and other lines.

Our story of engineering is primarily a masculine one. A compilation of some 1,300 graduates of Trondhjem's Technical College includes only 7 women, and apparently none of them came to America. Lucie Wennermark Nielsen, a graduate of Christiania's Technical College, is one woman, however, who enters the story. She came to New York in 1927 and took employment with Nestle's Food Company; after 1930 she served as research chemist for the Bristol Meyer Drug Company at Hillside, New Jersey.[42]

The number of chemical engineers who were born in Norway but received their technical education in this country is fairly large. Since this volume is not primarily concerned with these men, one of the group, Magnus Swenson, will suffice to illustrate the nature and extent of their influence. Swenson left Norway with his parents when he was only thirteen. The family went to Wisconsin and settled at Janesville; the son enrolled at the state university, from which he graduated in 1880. In preparing for his engineering career, Swenson wrote a thesis on "The Chemical Analysis of Madison Well Waters" at a time when the city was suffering from diphtheria and typhoid fever. Since the germ theory of disease had been recognized by only a few, Swenson's efforts as an employee of the city health department to study the sources of drinking water met with a determined opposition on the part of local citizens—but he succeeded and the epidemics were brought to an end.

Transferring to the newly created college of agriculture,

[42] *Norwegian-American Technical Journal,* vol. 2, no. 2, p. 11 (July, 1929).

Swenson experimented with sugar production from sorghum and in 1883 he was awarded a prize by the federal department of agriculture for a paper, "The Chemistry and Manufacture of Sugar." His studies brought him a position as manager of the largest sugar plant in the country, at Sugarland, Texas. Swenson has himself told what followed. Making changes in the factory and adding inventions of his own, he "had the very great satisfaction of nearly doubling the yield from the sugar cane. This led to my becoming consulting engineer to many of the sugar planters in both Texas and Louisiana." At about the same time he invented the Swenson multiple effect evaporator.

> [This] made it possible to remove the water from solutions very economically, and I received so many orders for this apparatus that I bought a half interest in the Fort Scott Foundry and Machine Company, Fort Scott, Kansas, in 1889, where I continued to manufacture until 1893, when we moved our plant to Chicago under the name of the American Foundry and Machine Company. . . . My work was principally the saving of waste. . . . [It] also extended into the manufacture of caustic soda, paper and pulp, licorice, tobacco products, glue, glucose, sugar of milk, tannin, and many others; but the manufacture of sugar machinery was my principal vocation.

In 1891 Swenson invented a quadruple multiple effect evaporator for Hawaii, "which I guaranteed to evaporate water from cane juice at the continuous rate of a ton of water a minute." Some years later he sold his Chicago plant; he returned to Madison, took a leading part in the development of hydroelectric plants on the Wisconsin River, and served as director of several business and financial firms. His fascinating career, discussed elsewhere in some detail,[43] included extensive service to state and nation; during 1917–19, he writes, "practically all my time was devoted to war work, as chairman of the Council of Defense for the State of Wisconsin, as United States Food Administrator for the State of Wisconsin, and finally in Europe as Chief of Mission of the American Relief Administration for Northern Europe, under Herbert Hoover." Among the many

[43] See Olaf Hougen, "Magnus Swenson, Inventor and Chemical Engineer," in *Norwegian-American Studies and Records*, 10:152–175 (Northfield, 1938).

administrative and executive positions that he held in his closing years was the presidency of the Norwegian-American Historical Association.

A note of nostalgia frequently appears in the lives of the immigrant engineers. Swenson, in writing of his home in Madison, on the west shore of Lake Mendota, says that he planted his fifty-acre plot of land with trees and shrubs "such as I remembered as growing where I lived in Norway. . . . This place I named 'Thorstrand,' after that part of Larvik where I lived as a boy. . . . On the window sill of my library there is fixed an arrow which points across Lake Mendota directly towards my old home. . . . Often when the lake is covered with mist I imagine that I see the old 'Thorstrand' on the opposite shore; and no Mohammedan turns his face towards Mecca more reverently than do I towards my childhood home." [44]

[44] Quotations are from a reply to a questionnaire sent to Swenson by the Norwegian-American Technical Society and published in its *Journal*, vol. 9, no. 1, p. 3, 6 (June, 1936). Other accounts of Swenson's career may be found in *Norwegian-American Technical Journal*, vol. 3, no. 2, p. 9 (August, 1930); George Edward V. Riis, "Magnus Swenson, a Doer of Deeds," in *American-Scandinavian Review*, 7:288 (July–August, 1919); *Scandia*, May 13, 1927; *Nordisk tidende*, August 9, 1928; *Minneapolis tidende*, February 11, 1932; *Skandinaven*, August 5, 1932, March 31, 1936, and April 7, 1936.

THE ENGINEERS ORGANIZE

THE educated Norwegian who arrived in America late in the nineteenth or early in the twentieth century could—if he had the time and the inclination—step right into a well-organized Norwegian life in any of the major northern cities. Naturally, many engineers availed themselves of this opportunity to relax with old friends, speak their native tongue, and forge new social links.

Many engineers have remarked that they took little or no part in such activities, but the records reveal that their participation was considerable. Here and there in the Norwegian papers appear names belonging unmistakably to the engineer group, linking them with this or that cultural, athletic, or social body. The simple fact is that the organized Norwegian life of the American city was there to be accepted or rejected; in either case it affected the engineer and formed a large part of the social and cultural pattern that was his in the New World.

I

Apart from the technical societies, the two organizations which were supported most warmly by the engineers were Det Norske Selskap of New York and the Chicago Norske Klub.

The Norske Selskap of New York grew out of the local Society of Norwegian Engineers and Architects, which had been formed in 1902 under the presidency of Carl Busch Thorne. Desiring a less restricted membership, the society reorganized two years later as the Norwegian Club, under the able presidency of Dr. Peter Groth. The dissolution of the Swedish-Norwegian union in 1905 spurred the new club into active life. For two years it maintained a reading room at the Hotel Imperial; then,

with a doubled membership, it took quarters on Clinton Street, and in 1913 it purchased a house at 7 St. Mark's Avenue in Brooklyn. The influx of young professional and business men from Norway during the First World War called for reorganization and larger quarters. Thanks to the efforts of the members and the generosity of Christoffer Hannevig, the Norwegian shipbuilder, a new clubhouse was acquired in 1918 at 117 Columbia Heights, overlooking New York across the East River. The four-story building in which the club is now housed was remodeled according to the plans of the architect Thorbjørn Bassø, and it includes, among other things, a dining room, clubrooms, a library, a ballroom, and living quarters for members and guests. From 40 members in 1904, the club grew to 88 in 1913 and over 200 in 1919. Especially active in the building project were such engineers as Anton P. Jæger, Gunnar Hartman, Johan Borge, Dag Sandberg, and the architect Bassø. Despite national depressions and frequent drops in membership, the club has survived as a vigorous organization to the present time.

While the Norske Selskap exists primarily for social activities, formal and informal, it also serves as a link between Norwegians on opposite sides of the Atlantic. Distinguished countrymen visiting New York — men like Roald Amundsen, Fridtjof Nansen, Worm Müller, C. J. Hambro, and others — have been entertained and in turn have lectured and frequently have lived at the clubhouse. Newcomers — young professional and businessmen — immediately feel at home in the New World in the company of club members, many of whom have themselves been in America but a short time. And through lectures, books, newspapers, and conversation, the organization has made possible a sustained interest in things Norwegian within a group that is constantly enlarged by fresh but small infiltrations of immigrants; these inject new life into the club at critical times.[1]

The Chicago Norske Klub, though formally organized in

[1] See *Norden* 1:19 (November, 1929); *Nordisk tidende,* October 8, 1925; and anniversary publications of the organization, especially *Klubnytt,* October, 1929.

1911, was the product of an amalgamation of two earlier clubs —the Norwegian Club in Chicago (Den Norske Klub i Chicago) and the Norwegian Quartet Club (Den Norske Kvartet Klub). The latter was twenty-one years old at the time of the union, and the other, six. The fusion was actually one of two generations—the older, in the prominent Quartet Club, and the younger, representing technical men for the most part, in the Norwegian Club. Wanting essentially the same thing—an organization of high social and cultural standards—and finding their membership somewhat interlocking, the two groups decided upon a union that would permit the chorus of the Quartet Club to continue as the singing society of the new club and to retain its affiliations with the Norwegian Singers' League of America. In the lists of Norske Klub officers the names of engineers have been numerous; of the 29 presidents since 1911, 11 have been engineers.

While the club building was being planned, the members met in other halls, and the directors at the Norwegian consulate. Lack of proper facilities apparently did not lessen the club's zeal in "the advancement of Norwegian cultural interests," but "the promotion of social intercourse among its members" was furthered by the acquisition, in 1911, of quarters at Kedzie and Milwaukee avenues. A story was added to the existing structure under Joachim Giaver's direction, and clubroom plans were drawn by Christian U. Bagge and Halfdan Strom. The new quarters included a lounge, a library, a small kitchen, and a hall seating 150 to 175 people; these improvements facilitated dinners, balls, lectures by prominent local leaders and visiting Norwegians, musical evenings, and general entertainment.

The attractive structure which now houses the Norske Klub at 2350 North Kedzie Boulevard is the realization of a long-felt need. Construction began in 1916. The financial problems involved in erecting such a clubhouse were overcome largely as the result of the energy and initiative of Birger Osland, a Chicago investment banker.[2] A total of about $26,000 was ex-

[2] For Osland's part in this project and for an account of club activities in Chicago, see his *A Long Pull from Stavanger,* 33–55 (Northfield, 1945).

pended for a lot and for the erection of the building, exclusive of the furnishings. When one considers that the membership was made up of lawyers, doctors, architects, engineers, journalists, bankers, contractors, and manufacturers, as well as of actors, musicians, and the like, it is not surprising that the necessary funds were forthcoming. Giaver donated his engineering services and Bagge designed the Norwegian fireplace; others contributed ornamental iron, carved wood trim, kitchen equipment, and a desk; and the wives decorated the interior with considerable skill.

The two-story brick clubhouse, when completed, was adequate to meet the varied needs of the members. The auditorium or hall on the first floor, with stage and dressing rooms; the clubroom, library, and bar on the second floor; and the dining room and kitchen in the basement offered ample facilities for the events that were to make the Norske Klub a real force in the life of the Chicago Norwegian element. The giant fireplace in the clubroom resembles a Norwegian *peis*; the lighting fixtures hanging from the ceiling are in the style of the old *stabbur*; and the general atmosphere of the clubroom interior — derived in part from pilasters, ceiling beams, and decorations — reveals at once the influence of Old Norway.

In scope of interest the Chicago Norske Klub has no rival outside of Norway. Singing, dramatics, art exhibits, meetings of various auxiliary groups, conventions, royal visits, and many another activity have added color and significance to the institution, which continues to function despite the drying up of the immigration stream and the consequent drop in membership. Of the total membership of 276 in 1917, 57 were engineers, and of the total of 196 in 1945, 54 were engineers — these figures revealing at a glance what the Chicago Norske Klub has been in the life of this technical group. A young engineer arriving in Chicago would go straight to the club, meet old friends from the technical school, and establish at once the necessary contacts for employment as well as for social life. There, too, he could read papers and books from the homeland

and join with the members in the sentimental club song. It was written by Olaf Schroeder in 1906 for Den Norske Klub i Chicago, whose members, almost all of them then new arrivals, were stimulated by the events that led in 1905 to the severence of Norway's union with Sweden:[3]

KLUBSANG

Leiret i et enigt fylke
Staar vor klub for Norges sag.
Og vi løfter høit vort merke
Her i norskhets vennelag.
Vi vil mindes hav og fjorde,
Mindes skoge, dal og fjeld,
Og hvis du os kræver Norge,
Slaar vi skjoldborg for dit vel.

CLUB SONG
[Translation]

Gathered now in common purpose,
Hearts aglow with warm emotion,
In Norway's cause our banner's hoisted,
Here in friendly Norse devotion.
Yes, we cherish sea and forest,
Well remember fjord and height,
If you need us, dear old Norway,
For your honor we will fight.

II

In the Twin City area not a little of the engineers' early social activity centered in the person of Carl Illstrup, who entered the Minneapolis city engineer's office in 1882. Short, stocky, and cheerful, the "Little Napoleon," as he was sometimes called, plunged with terrific energy into the life of the Norwegian community and justified his actions in these words, "For many

[3] The best sources of information about the Chicago Norske Klub are two booklets, one published when the clubhouse was dedicated in 1917, the other in 1930 in observance of the organization's fortieth anniversary: *Chicago Norske Klub, Historical Sketch Published on the Occasion of the Dedication of Its New Club House, 2350 North Kedzie Blvd.* (Chicago, 1917), and *Chicago Norske Klub, 1890–1930* (Chicago, 1930). Also valuable is *Norden,* 1:11, 23 (March, 1930).

years [immigrants] experience a feeling of having left something behind, a sense of being in a strange environment, and we never feel so good as when we are able to meet with our countrymen and hear and talk our native language."[4]

Illstrup organized the Minneapolis Ski Club in 1882 and served as its first president, at a time when skis were not only unobtainable but also locally unknown. "We used to ski over the spots on which are now located some of Minneapolis' finest residences," Illstrup wrote later, "but the ideal skiing places were where the Washburn home now stands, and on Lowry Hill. . . . Ordinarily, we took our girls with us, and with a bit of practice we could take them on our skis, in our laps or on our backs, when we went down a hill." Clubs were established in St. Paul, Stillwater, Eau Claire, Albert Lea, Hudson (Wisconsin), Red Wing, Duluth, and Ishpeming (Michigan), and in 1886 the Ski Association of the Northwest, with Illstrup as president, was formed of all these groups.

Even earlier, in 1885, a ski meet was scheduled by the clubs. The Minneapolis members "went out among the wealthy citizens . . . to stir up enthusiasm, and incidentally some money, for the project. We had quite good success, and secured a few hundred dollars for uniforms and other expenses. The uniforms selected were blue woolen with grey trimmings all over them, and were made on the order of the lumberjack's suit." At the tourney Mikkel Hemmestvedt, then the leading skier in Norway, "carried off all our first prizes. He made what was considered then a magnificent jump — of 90 feet." Subsequently there were two years without snow; the members "grew disheartened, and gradually the organization broke up. After that everybody became too busy to revive the old ski runs, and they have not been organized since."[5]

In 1883 *Budstikken* appealed to the Norwegian community in Minneapolis to organize a gymnastic society. It was founded

[4] From one of many Norwegian speeches found in Illstrup's papers; this quotation is from an address delivered at a Christmas gathering about 1900. The Illstrup papers consulted by the present writer are in the possession of Mrs. Walter Fuchs of Douglas, Minnesota.

[5] From an account prepared by Illstrup's hand and found in his papers.

in December, 1885, as Den Norske Turnforening, with Illstrup as president. The turners met first at Peterson's Hall, then at Rifleklubbens Lokale on Third Street, and in 1886 they moved to Minnehaha Avenue near Cedar Avenue. When the first instructor left, Illstrup took his place, and the turners participated in meets at Minneapolis and elsewhere, notably Chicago. In June, 1893, the Northwestern Athletic Club, an "international" organization, was started by a handful of gymnasts, among them Illstrup. With headquarters in Normanna Hall, a great center of Norwegian activities, the club had a well-equipped gymnasium that was the product as much of enthusiasm as of the financial resources of the members. Illstrup served not only as president but also as instructor in the "building of muscle and manhood."

As the size and reputation of the club grew, it added many "passive memberships," from business and professional men wanting good will and patronage. A series of public exhibitions culminated in a grand three-night performance at the Lake Harriet pavilion in the fall of 1896.[6] The greatest success came in the years 1893–96 when, among other things, the organization promoted skating and helped to produce such famous performers as Axel Paulson, Harold Hagen, and "Speed" McCormick. The club died in 1900 but the officers and some of the members continued to get together for years thereafter.[7]

Worth noting in connection with Illstrup's athletic activities was a tug of war tournament held in 1888; the "Little Napoleon" organized the Norwegian team of ten men that won the contest, and the Minneapolis papers were full of praise for the way he led his men on to one victory after another.[8]

Despite Illstrup's many muscle-building activities, he had time to give to the Scandinavian Dramatic Society (Skandinaviske Dramatiske Selskab) in the 1880's. His were comic

[6] Knud Holen, "A Bit of History," in the *N. W. A. C. Sexa,* an undated sheet published by the Northwestern Athletic Club of Minneapolis. A copy was found in the Illstrup papers. Holen's article carries the date March 24, 1900.

[7] *Minneapolis Daily Star,* December 31, 1932.

[8] *Norsk sportsblad,* 1:1 (January, 1916). A copy of this number is in the Illstrup papers.

roles — such as Departements-Lars in *Petter og Inger* and Per in *Til Sæters* — and we can believe that he put much of himself into the performances that were given in Minneapolis and near-by towns.[9] He was also a member and at one time president of the Odin Club, at whose meetings he expressed sentiments in favor of the common Scandinavian tradition with almost as much intensity as he spoke for the Norwegian heritage before purely Norwegian societies.

Though none of the other Twin City engineers shared Illstrup's enthusiasm for the glow that follows physical exercise — a biological phenomenon that he discussed frequently and in detail — others there were who took willingly to the ski sport and to other activities that he loved so much. Hugo Kolstad and Martin S. Grytbak, for example, were members of the St. Paul Ski Club, which used a hill at Red Rock before moving to West Seventh Street near Otto Avenue (Highland Park).[10] Kris Oustad and F. W. Cappelen in Minneapolis were, like Illstrup, members of the Odin Club in the days when it maintained a chef and served lunches, besides putting on parties in hired halls. And others like O. M. Rognan belonged to musical societies such as Fram and Orpheus.

Characteristic of the informal gatherings common among engineers was a "Boston" club organized by Hugo Kolstad, Alf Munthe, Adolph Andersen, and Martin S. Grytbak, with Haakon Falk as a substitute. Later a similar group, including Jacob Anthonisen, R. A. Tanner, and O. M. Rognan, was started. At first these men met every Saturday evening, later every two weeks, and finally once a month, to play Boston, a card game that was popular among people of their class in Norway; some-

[9] Carl G. O. Hansen, in *Skandinaven*, September 11, 1936.

[10] It was not only in the Twin Cities that engineers pioneered in the ski sport. Marthinius A. Strand of Salt Lake City is credited with introducing skiing on the sports level to the people of Utah and surrounding states; he has served as president of the International Ski Association and as vice-president and director of the National Ski Association. In British Columbia Robert Lepsoe, in 1928, was the prime mover in organizing the Trail-Rossland Ski Club, which he served as president. "Many of the places where once my family and I used to ski in seclusion," he writes, "have become ordinary play grounds and even the highest mountain ridges are now overrun with tracks." Sigurd O. Rogde, a Bergen graduate, has been sports director for the Norsemen Ski Club in New York City; in 1941 he was elected president of the club.

what resembling auction bridge and requiring special chips, the game supposedly originated among French naval officers stationed at Boston during the American Revolution. Apparently it served well for a stag evening of drinks, smokes, and Norwegian conversation.

The engineers who arrived in St. Paul after 1904 — many of them to work in the railroad offices — could establish immediate contacts in the local Norske Klub, which had engaged a room in Central Hall (now the Fisher Building) for its programs and dances. Here they might meet such men as Johannes Lie, the first president, Hugo Kolstad, Martin Grytbak, their wives, and others. As was also the case in other cities, this club came into being simply because its members felt not entirely at ease in the older Norwegian organizations of St. Paul. Active until 1912, the Norske Klub of St. Paul enjoyed a brief revival thereafter but soon ceased to be a strong force in the lives of the engineers.

III

Though engineers came to America in fairly large numbers after the 1880's and though they frequently met together — at a common table, perhaps, in a room over some saloon, or at the home of one of their group, and sometimes even organized clubs of technical men like the Society of Norwegian Engineers and Architects in New York — it was not until the prosperous 1920's that the present influential technical societies were started.

The graduates of Trondhjem's Technical College living in Chicago established the custom, in 1912, of celebrating, each November, the anniversary of the founding of their alma mater. The *Novemberfest,* as their gathering was called, was not unlike similar alumni meetings held everywhere in the United States. About twenty engineers and architects were regularly in attendance at the get-together, renewing acquaintances and carrying away pleasant memories of a thoroughly good time. At the *Novemberfest* in 1922, however, a significant step was taken; those present decided to invite all Norwegian engineers

in Chicago, regardless of which school they had attended, to participate in the annual gathering. At this meeting, too, the Chicago Norwegian Technical Society was organized; it had a charter membership of 39, and Joachim Giaver was the first president. Monthly meetings were scheduled, with programs of lectures and informal entertainment, and around November 1 of each year a formal banquet and dance took place.

A glance through the minutes of the society reveals some interesting programs and activities. At the meeting of February 3, 1923, when the formal organization of the enlarged group was effected, "Our final act was to eat and drink in modern style, without wine and beer." Lectures on technical and nontechnical subjects were delivered by members and distinguished guests; it was decided to publish a yearbook; the status of the engineering profession was discussed; and considerable horseplay centered about the admission of knights to the order of Den Halvtømte Flaske (The Half-emptied Bottle). Several noteworthy decisions were made during the early years of the Chicago society. One was the plan, inaugurated in 1925, of gathering records of the work of Norwegian engineers in Illinois; the resulting program, later expanded to cover the entire country, took on the nature of a major contribution. Certainly, as the new president, I. H. Faleide, suggested, a study would one day be made of the careers of the Norwegian technical men in America. In the spring of 1927 preparations were made for a national congress, in Chicago, of Norwegian engineers in the United States and Canada, and in connection with this gathering it was agreed that it would be desirable to organize a national technical society. In 1926 the Chicago society also set up a service bureau to assist young engineers in finding employment, a project that was later expanded to assist experienced men in obtaining new positions commensurate with their abilities.

Lectures were a worth-while feature of the regular monthly meetings of the Chicago engineers. Among others, during the years 1928–33 Thomas Pihlfeldt discussed "The Straightening

of the Chicago River"; Alfred Alsaker analyzed "The Economic Equation"; Sigurd E. Naess described "Chicago's New Post Office"; and a guest speaker from the University of Chicago lectured on "Technocracy." In the dark years after 1929 there was a growing demand for lectures on economic and social problems; technical subjects, however, never ceased to dominate the program. As for social life, two events crowned the season — the *Novemberfest* and the annual dinner dance in the spring. A novel and significant educational feature was introduced during the winter months of 1928–29, consisting of courses in plan reading and estimating for craftsmen in the building and construction field. The educational program, like the employment service, was supervised by Thomas Pettersen, and the classes, which were free, were held in the rooms of the Crane Technical Evening School.

During the years 1923–29 the Chicago society grew in numbers and organic strength. From 39 the membership jumped to 150, the work of collecting biographical data progressed slowly, and before the financial crash of 1929 the members were dreaming of building a Norway House; Viehe Naess and Bagge were drawing plans for a 20-story structure that would house all Norwegian organizations in Chicago. Needless to say, the closing months of 1929 drew a curtain on such optimism, and membership rapidly declined. For a time the society held meetings at the Masonic Building in Logan Square; later the headquarters were moved back to the club, which is still the center of activities.[11]

IV

Elsewhere, similar groups had taken form. At Schenectady, where the General Electric Company and the metal industry offered excellent opportunities for employment and practical experience, a Norwegian Technical Society flourished in the days before and after World War I. Schenectady lies on the

[11] A good brief history of the Chicago Norwegian Technical Society appeared in *Scandia,* April 7, 1938; Thorleif B. Jorgensen has reviewed its early years in *Norwegian-American Technical Journal,* vol. 1, no. 1, p. 6 (February, 1928); other accounts may be found in subsequent issues of the same periodical, and such papers as *Scandia* and *Skandinaven* faithfully reported all meetings.

route of the immigrant journey (New York-Albany-Buffalo-Chicago), and as a result the membership of its society has fluctuated with the ups and downs of immigration.[12]

The success of the Chicago society served as an inspiration to the young engineers of the New York area to organize a new club. A small group of men, accustomed to gathering of an evening in the apartment of John Litell and Sv. Steen Sandal, decided to effect a more formal organization; this was done on January 26, 1925. The Norwegian Engineers' Society of New York was started at the clubhouse of the Bergen Association; about 40 engineers became members and Ola Sater was chosen as the first president. Early meetings were held in the rooms of the Norske Selskap on Columbia Heights, and the programs did not differ materially from those of the Chicago engineers.

In 1926 two rooms were rented as headquarters at 418 Fifty-fourth Street, in Bay Ridge, within easy distance of the homes of most of the members. During the second year of its life the organization, in co-operation with the Swedish Engineers' Club, began a vigorous effort to secure suitable positions for young technicians and, under the presidency of O. L. Riegels, took a stronger interest than before in social life. More adequate quarters were then found at 561 Fifty-second Street; these rooms were open to members every evening and the evidence points to an enlarged membership and a generally increased interest in the activities of the society. In December of 1927 the group joined the Norwegian-American Technical Society. Regular meetings drew an average attendance of 30, and the bachelors, in particular, were happy to use the club's rooms as a substitute for ordinary home life. Interesting, too, was the society's determination to support all worthy Norwegian-American movements and at the same time to foster its own professional and social needs.[13]

It is significant that by 1928, if not earlier, the interests of

[12] See *Nordmands-forbundet*, 6:144 (1913) and 11:471–473 (1918).

[13] See an article by John Litell, corresponding secretary, in *Norwegian-American Technical Journal*, vol. 1, no. 1, p. 9 (February, 1928); an able ten-year review of the society's history was written by John Litell and Sv. Steen Sandal and published in the *Journal*, vol. 8, no. 1, p. 5, 20 (November, 1935).

the New York society were extending beyond the purely technical and social fields. Lectures on such subjects as "F. W. Taylor, His System and Its Influence on World Industry," "Our City Government," and similar topics of a political and economic nature must have left their impress on the members. In 1931 a forum for the discussion of social problems was inaugurated under the sponsorship of S. J. Stockfleth. Frequent references in the programs to readings, such as excerpts from the Norse sagas recited by Dr. Frithjof Zwilgmeyer, indicate that literature was not ignored; and music, much of it of Norwegian origin, was a constant feature of the meetings.

Of special interest was the establishment, in the spring of 1928, of a free evening trade school for carpenters, bricklayers, and the like, similar to the one in Chicago. The idea originated with E. J. Oland and the purpose was to give complete courses in blueprint reading, estimating, and construction. Such was the enthusiasm of the tradesmen that almost overnight 120 men had applied for admission. Of this group only two classes of 25 members in each could be accommodated in the clubrooms. Nothing daunted, the teachers consulted with the local board of education and secured the use of classrooms in a public-school building.

Three classes were taught during the fall of 1928 and the spring of 1929. Ola Sater, who had had teaching experience in Norway, was the principal instructor; he was assisted by O. Lowzow, B. Paulsen, F. Oyen, and S. S. Sandal. In 1928–29 two special courses in structural design for engineers were also conducted by the society. The school was unable to continue its program in the fall of 1929 and the depression that followed no doubt discouraged further educational ventures.

The need for larger quarters became so great by the spring of 1929 that new rooms were rented at 515 Ovington Avenue, in Bay Ridge. The location was not ideal, but many bachelors moved nearer to the clubrooms and the doors were open every day. Regular meetings were held on Friday nights and informal dances were usually scheduled for Saturdays. A capable steward

served excellent four-course Norwegian dinners every evening as well as sandwiches and beverages. The building was in an unfinished condition, so the clubrooms were partitioned off and decorated at the expense of the society, with the understanding that the financial outlay thus involved would be deducted from the rent. Unfortunately the owner of the building was soon declared bankrupt, the members lost their personal investment, and a painful interval followed. The society was forced to sublet its rooms and in 1931 it wisely incorporated. During the same year less expensive headquarters were rented at 530 Eighty-sixth Street, where the society still meets. After the worst of the depression, during which engineers in considerable numbers resigned and some even returned to Norway, there was renewed interest and an increase in membership, which in 1935 totaled more than 80.

The Norwegian Engineers' Society possesses excellent clubrooms. In them are held the annual *høstfest* (fall party) in September, a social gathering each month, a *herrefest* (men's banquet) in December, a children's Christmas party, a New Year's party, and a Seventeenth of May celebration. There is talk of a new clubhouse, and a fund was started in 1938 toward the realization of this objective. Corporate feeling was enhanced in the same year with the publication of the first issue of the *N. E. S. Bulletin,* which like the *Journal* of the national engineers' organization contains biographical material, in addition to news of local interest. After the invasion of Norway in 1940, the engineers in the East took a special interest in Norwegian fliers and seamen, raised funds for the benefit of the Seamen's Church in Brooklyn and the engineers on Norwegian ships, and, like Norwegian-American groups in other places, gave assistance wherever possible to the cause of freedom and reconstruction in the homeland.

V

The idea of a national organization had gestated for years in the minds of some of the engineers. Consequently when the Chicago Norske Klub, under the presidency of Birger Os-

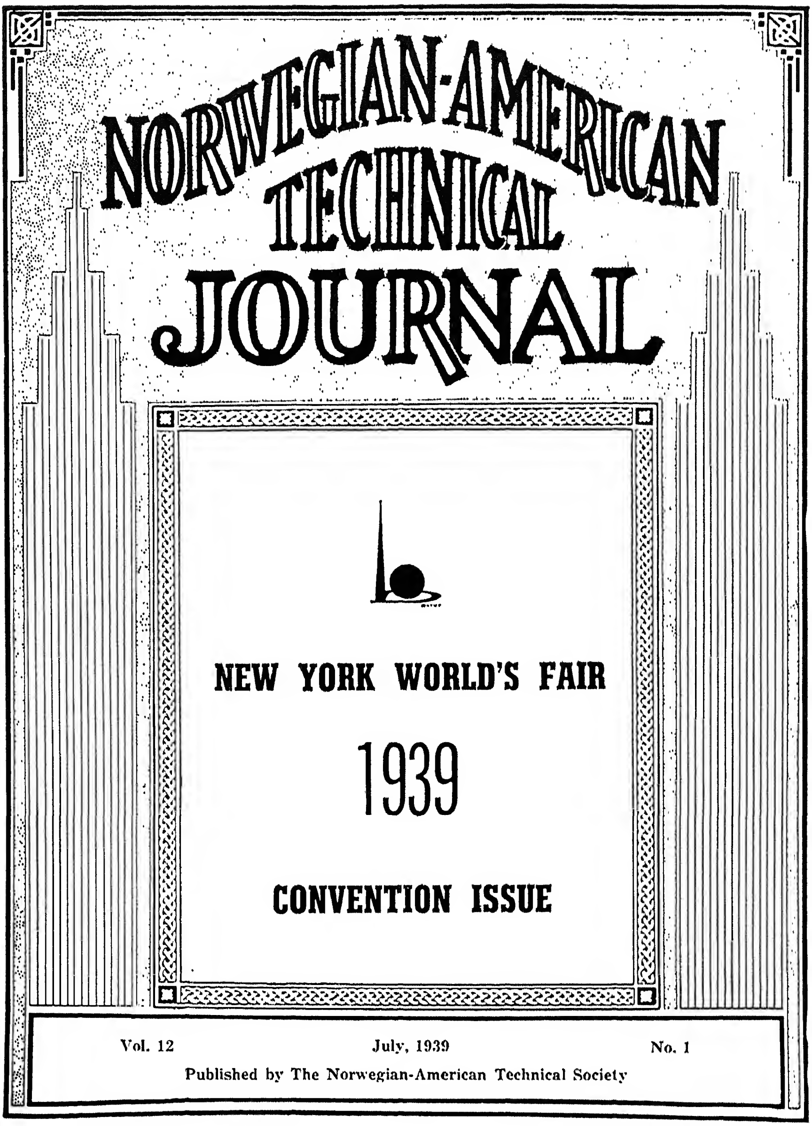
land, sponsored a convention of Norwegian engineers and architects in 1917, the gathering that followed was a notable success, despite the clouds of World War I. A committee appointed by the Norske Klub and composed of Giaver, Pihlfeldt, and Viehe Naess in Chicago had sent out invitations before America's entry into the war; having done this, they were determined that the convention should be held. During the last three days of September about 80 technical men from outside Chicago mingled with approximately the same number of local members. Among those who attended were F. W. Cappelen of Minneapolis, Søren Munch Kielland of Buffalo, Magnus Swenson of Madison, Hans Helland of San Antonio, Olaf Hoff of New York, and many others who have figured prominently in this story. A strong patriotic spirit, which was expressed in a resolution of loyalty to the government of the United States, naturally pervaded this first gathering of Norwegian engineers in America. On the last day of the convention a formal organization was effected, with Joachim Giaver as president.[14]

Almost exactly ten years later a second convention was held at the Norske Klub. Jointly sponsored by the club and the Chicago Norwegian Technical Society, this gathering was planned by a committee under the chairmanship of Thomas G. Pihlfeldt. About 125 men responded to the invitation and the convention sat from September 22 to 24, 1927. Judged by the official report, the social side of the meeting as well as the technical was a complete success. From the historical point of view, however, the most significant result was the formation of the Norwegian-American Technical Society. A constitution, with bylaws, was prepared by C. F. Berg and A. H. Nesheim; it was submitted on the closing day of the convention and approved. The scheme proposed was one of direct memberships for technical men residing in cities where no branch group could be formed, and for branch organizations in the more important engineering centers.[15]

[14] See Osland, *A Long Pull from Stavanger*, 45; F. S. H. Sartz, "Det norske teknikermøte i Chicago," in *Nordmands-forbundet*, 10:463–467 (1917).

[15] See G. A. Viker's account of the convention in *Norwegian-American Technical*

Directors' Meeting, 1929, Chicago Norwegian Technical Society, in Chicago Norske Klub (E. M. FASTING, ALF SELROD, ERLING NORMANN, THOMAS PETTERSEN, A. H. NESHEIM, PETER SANDVED, ROAR KNUDTZON, IVAR VIEHE NAESS, CHR. U. BAGGE)



Convention Issue, Norwegian-American Technical Journal

A major purpose of the new organization, we read in the constitution, was "to keep records of their [*the engineers' and architects'*] progress and achievements"; the bylaws list as one of the duties of the board of directors the publication of a journal to appear at least four times a year. It was also decided at the Chicago convention that one of the two branch societies should be named to carry on the work of the national organization between conventions. This task has been assumed by the Chicago group.

The next convention was likewise held at Chicago — during the Century of Progress Exposition, from June 22 to 24, 1933 — and again the Norske Klub was the scene of activities. The exposition naturally offered a variety of exhibits of interest to engineers; among them was one displaying the Tinius Olsen testing machines. At a business meeting it was disclosed that, despite the depression, the national organization had a total membership of 330. Otto Clausen, secretary of the organization, announced that twelve issues of the society's *Journal*, which he had edited, had been mailed to members, libraries, and educational centers.[16]

The fourth convention was held in New York, September 2–5, 1939, during the World's Fair in that city. This time the eastern society sponsored the gathering; a committee headed by S. J. Stockfleth made it a notable one. At the opening session the present writer explained to the members of the society the tentative plan of the Norwegian-American Historical Association to study the engineer group and in due course to publish in book form an analysis of its contributions to American life and growth. The plan as outlined was wholeheartedly endorsed.[17]

The task of publishing such a book has been made immeasurably easier by the material appearing regularly in the *Norwe-*

Journal, vol. 1, no. 1, p. 4–6 (February, 1928). The constitution and bylaws are printed in vol. 1, no. 2, p. 14 (May, 1928).

[16] See *Supplement to Norwegian-American Technical Journal*, August, 1933, p. 3.

[17] See *N. E. S. Bulletin*, no. 2, p. 5 (December, 1939). An article by H. Sundby-Hansen in *Nordisk tidende*, September 7, 1939, and another by Carl Matre in *Skandinaven*, September 15, 1939, give detailed records of this convention.

gian-American Technical Journal. No less than twenty issues in all have been published and these contain, in addition to news of the society and its branches, invaluable biographies of outstanding engineers and articles dealing with specific technical projects. That much information has thus been saved for the historian is the result of the combined efforts of the members of the society, but a special word of praise is due the men who edited the beautifully illustrated *Journal.* Otto Clausen, who is a musician, not an engineer, has nevertheless edited fifteen numbers;[18] S. J. Stockfleth, Petter Moinichen, and C. F. Berg each was responsible for one issue; and Magnus Bjørndal was editor of two successive *Journals.* C. F. Berg in Chicago and Magnus Bjørndal in New York have been particularly active in collecting biographical material.

In another closely related way the national organization of engineers and architects has added to historical knowledge. The leaders had in mind the collection of data pertaining to their own group, and the first issues of the *Journal,* beginning in February, 1928, contained valuable information. But it was not until the spring of 1934 that the branch societies in New York, Chicago, and the Twin Cities were asked to designate committees specifically charged with the duty of gathering source materials. The committees compiled lists of engineers and architects, and prepared questionnaires, asking the usual questions about one's life and work, that were sent to these men. The results were at first disappointing, but gradually, in response to various pressures, an impressive collection of data was accumulated from both sides of the Atlantic.[19] Some, but far from all of the information thus obtained was utilized in preparing the interesting biographies published in the *Journal.* The archives of the Norwegian-American Technical Society are kept at the headquarters of the Chicago branch.

Branches of the national society were soon to be organized

[18] For an account of this interesting singer and choral director, see *Skandinaven,* July 13, 1934.

[19] See "Wanted: The Records of Our Engineers and Architects," by C. F. Berg, in *Norwegian-American Technical Journal,* vol. 8, no. 1, p. 7 (November, 1935).

in the Twin City and Philadelphia areas. M. S. Grytbak, a member and director of the national organization, gathered old associates at his home early in 1929, and the outcome of the discussion that followed was the Northwest Branch. In February of the same year some twelve men became members and Grytbak, city bridge engineer of St. Paul, was elected president. There have been regular meetings, largely social in nature, with "Boston" and bridge games, occasionally interrupted by lectures on technocracy and specific engineering projects.

At the New York convention of the national society, in 1939, the question of additional branches was discussed. Philadelphia was the first city to act. Dr. Haakon Styri, of ball-bearing fame, aroused enthusiasm among local engineers late in 1941 for a Norwegian-American Technical Society of Philadelphia. The organization was realized in May, 1942; the 34 members chose Styri as their first president.

One example of another type of local technical organization, to which many Norwegian engineers belonged, will be mentioned. This is the Swedish Engineers' Society, a member of the Associated Technical Societies of Detroit. It was common, especially in the nineteenth century, for Americans of Scandinavian birth to gather in organizations of all kinds, and engineers were no exception. The number of Scandinavian engineering societies, informal and formal combined, that sprang up in the cities and industrial sections of this country must have been considerable, since reference to this or that group, usually long since extinct, appears in many biographical accounts of the Norwegian engineers. But in the twentieth century the trend in such cities as Chicago and New York was distinctly toward separate Swedish and Norwegian societies. Together with a friendly rivalry between the national groups went considerable co-operation and an occasional exchange of visits — a practice that extended also to the German societies.

In Detroit, however, the Swedish Engineers' Society was the common Scandinavian technical organization of the 1920's, and it prided itself on being the "youngest and liveliest of the

Scandinavian engineering societies in the world." Its monthly *Bulletins* for 1924 show that the directors were chosen to represent not only the Swedes but also Finns, Danes, and Norwegians; acting for the Norwegians were Sigmund Janson and N. H. F. Olsen. Olsen also served as chairman of the editorial committee. In its most ambitious period the society planned a convention of Scandinavian engineers at Detroit; this, however, was never realized.

VI

Speaking in 1929 at the twenty-fifth anniversary dinner of the Norske Selskap in Brooklyn, B. B. Furre, charter member and loyal supporter of the club, set out to answer a question that has frequently risen in the American mind. The topic of his address, which was delivered and published in Norwegian, was this, "Is the Norwegian Club Justified?" [20] Some of Furre's statements are of more than usual interest in determining the attitudes of the members of this and similar immigrant organizations. The club, he maintained, rendered a distinct service and the members received satisfactions beyond definition when distinguished Norwegians were entertained during visits to America. "Norway is a country with an old culture. America is an immigrant land." Consequently, in Furre's words, a person "reared in a Norwegian home, educated in Norwegian schools, surrounded by old traditions and culture, wants and has the right in this country to the social and fraternal life that he can find in a Norwegian club like ours, and I maintain that eventually he is a better American for it." He continued: "And here we arrive at a truth that has been so often stated — a man who is not a good Norwegian cannot be a good American. I think one can say — no, I am positive that one can say — that the quicker the immigrant sheds his Norwegian character, the smaller the loss to Norway and the smaller the gain to America which accepts him as a citizen; and the less he becomes, as an American, the power that is needed to elevate the national life, political and cultural, of the United States." Furre made it

[20] *Klubnytt,* October, 1929.

abundantly clear, however, that it was the duty of every immigrant to become an American, to assume the duties of citizenship, and to be associated in every way with the best in the adopted land. But it was his considered opinion that the more cultured and educated the person, the greater the tragedy —and failure—when the transplanted Norwegian lost his heritage and identity.

Addressing the engineers more directly and brutally, Magnus Bjørndal went on record in 1930 in defense of the increased social activities of the Norwegian Engineers' Society of New York. "Most of the members," he wrote, "may have a large number of friends, but these are often spread over the large city and suburbs, and therefore social intercourse is limited except among a little clique of friends in the immediate neighborhood." Because of this, "most engineers shun the clubs, churches and societies which are entirely of a social nature." The engineers, it should be remembered, are Europeans in training and mentality. "For all who as yet have life in the old country freshly in mind there is a certain natural craving for social entertainments which, to be really 'stilig' [*stylish*], must find everybody in evening dress, with everything that goes with it." Bjørndal was convinced that "most of the younger engineers, who have come here during the last ten years, have entirely too little social intercourse to be able to develop themselves so as ever to amount to anything. This is especially true of that large number of men who do not belong to any society or club whatever." He continues:

> In the beginning they can not afford to—they have debts to pay; and, later, they become too shy to take up normal relations with their fellow humans. They dig into a furnished room and become perverted hermits who are real dangers to civilized humanity. The most fertile years of young manhood are wasted. During the years when acquaintances should be made and personalities built up by learning from others, these unfortunates waste their time around a card table in the company of a couple of friends who are as empty as they themselves; or they may be found sitting deaf and dumb in a restaurant, staring into the smoky atmosphere while daydreaming of things that one would like to do but never does. Dozens and dozens of examples

of such men can be found among the younger Scandinavian engineers in this country, who . . . contemptuously look down on everything, are dissatisfied with their positions, and complain about the rotten conditions in this country.[21]

It is possible, of course, to argue that men like Furre and Bjørndal overstate the case that can be made for the immigrant professional society. This is true if one looks merely to the social and technical activities and ignores the subtler cultural influences. The formal banquets and dances are substantially the same as those of other non-immigrant professional groups. The evenings devoted to business and technical matters, in turn, compare with meetings of the various branches of national engineering societies, and it is fair to assume that the caliber of the lectures is not above those given elsewhere before small gatherings of engineers.

The gay side of meetings and conventions finds expression in such songs as this one, that might open a festive event in Chicago:

VOR FORENING

Velkommen venner, velkommen vær!
Ta plass, hver mann i salen.
Vær hilset alle til festen her,
vi løfter høit pokalen!
Det første beger vies skal
vor ungdoms kjære minner,
som nu i festens lyse hall
oss brødre sammen-binner.[22]

OUR SOCIETY

[Translation]

Welcome, friends, welcome, I say!
Attention, every man in the room.
Greetings to all on this festive day;
Let's drink and chase the gloom!
Come, a glass for one and all;
Think of our youthful days,

[21] *Norwegian-American Technical Journal*, vol. 3, no. 2, p. 5 (August, 1930).
[22] First stanza of a song written by Alf Selrod; sung to the tune of "I Rosenlund."

Which here in bright-lit hall
Bind us as brothers in praise.

Or the engineers might sing their "Welcome Song," as they did at the stag dinner given at the New York convention in 1939:

Velkomstsang

Herre-Fest vi feirer nu ikveld; fallera
Vi gamle guttene, her for oss sel', fallera
Kom la oss drikke ut vort fulle glass, fallera
For all teknik hurra! Og si ei pass! Fallera.[23]

Welcome Song
[Translation]

Tonight we men will have our fling; fa-la-ra
We frisky oldsters, here by ourselves, fa-la-ra
Come, let's down our brimming cups, fa-la-ra
Hurrah for the engineers! And never a care! fa-la-ra

A great deal of enthusiasm would go into the singing of the "Roundup":

Rundupp

Fulle glass i godt kalas,
det er ikke på sin plass,
så sa gamle Peter Dass,
— altså tømmer vi vårt glass.
(Der skåles og drikkes.)
Videre sa Peter Dass:
Tomme glass i godt kalas,
det er ingen vert tilpass,
altså fyller vi vårt glass.

Roundup
[Translation]

Carefree feast and full-up glass,
This can surely never pass,
So at least said Peter Dass—

[23] First stanza of an adaptation of the "Velkomstsang" of the Chicago Novemberfest; also written by Alf Selrod.

Well, then, empty each his glass.
(Toasts and drinks.)
Further said our Peter Dass:
Good carousal — empty glass,
That's indeed a sorry pass,
So let's fill the empty glass.

There was real value in the discussions following lectures, the experience gained in public speaking, the conviviality that carried away the strains and worries of the workaday world, the friendships formed, and the positive professional gains that accrued from such gatherings. Parenthetically, it might be added that some of the immigrant engineers who could be enticed to attend the meetings of the Norwegian-American Technical Society have taken no part in professional organizations of the usual sort; a distinct service has thus been rendered. And few there are today who would not approve the sympathy and financial aid extended by the engineers to Norway during her recent trials under Nazi tyranny. Especially noteworthy was the collection of $5,000 for the purchase of scientific and technical books presented to the Institute of Technology and the Royal Academy of Science at Trondhjem.

Indeed a remarkable change, at least among educated people, is discernible in the American attitude to the immigrant, and World War II has come and gone without the amount of intolerance that characterized the First World War and the years immediately following. It is now generally acknowledged that while our civilization "will always wear a certain well-defined American character," it is also "perforce cosmopolitan and, like all traditions, subject to growth and change." [24] The *American-Scandinavian Review* fought a good fight against the national egotism and bigotry that were among the saddest consequences of World War I. In fact, it cautioned immigrants against suppressing "national and individual characteristics in an effort to subordinate themselves to the Anglo-American cultural mould,

[24] "Americanism," an editorial in the *American-Scandinavian Review*, 4:49 (January-February, 1916).

which is sharply defined and in many ways narrowly limited within hard and fast boundaries," and reminded them that to their mother country they owed "all that is best" in their makeup. External forms, dress, "social customs, stereotyped phrases and ideas" assume a far greater significance than they merit, and if they are unthinkingly acquired, these result in a population characterized by a "colorless uniformity"—one lacking in the "ferment which is otherwise active wherever outside elements are introduced."[25] The older American need not fear the immigrant, certainly not the Scandinavian immigrant. "Assimilation in its psychological aspects may be regarded as an organic process, not unlike the naturalization of a plant transferred from one soil to another. Too much urging and forcing . . . is like tampering with the roots of the plant." Generally speaking, the best attitude to assume toward the immigrant, apart from the hospitality that is traditional in America, is to "leave him alone. Nature will do the rest."[26] Another author has maintained:

> Objections raised to the gathering together in national groups . . . are really of a short-sighted nature. . . . It would be an inhuman restriction to prevent a person from going where he can hear and speak his mother tongue. And where aid and sympathy is required, it is not only natural but desirable that these be rendered in groups. Futhermore, this feature is not solely characteristic of the immigrants. In every country, even where there is no immigration, clubs, societies, religious bodies, local gatherings for set purposes, are common. Why should immigrant association be deemed offensive?[27]

VII

These thoughts are recorded not only because immigrant organizations have had to contend with disapproval, if not opposition, from the general public, but also because within the immigrant group itself there is considerable hostility to the separateness supposedly inherent in organizations such as the

[25] William Hovgaard, "The Mission of the American-Scandinavian Foundation," in *American-Scandinavian Review*, 5:220–225 (July–August, 1917).

[26] William Hovgaard, "Americanization and the Native Languages," in *American-Scandinavian Review*, 7:270–272 (July-August, 1919).

[27] Oscar Gundersen, "The Immigrant," in *Norden*, 3:6 (December, 1931).

Norwegian-American Technical Society. Serious charges have frequently been made by Norwegian engineers of wide reputation that Norwegian-American organizations absorb much of the time and energy of young men who should be concentrating on technical problems, perfecting their English, and generally identifying themselves with what they call "American life" and "Americans," rather than forming "colonies" in the New World. Some of these engineers have attributed their own professional success to the ability to remain aloof if not entirely apart from Norwegian-American activities; others, they imply, would do well to follow their example, particularly those who feel discriminated against because of their foreign origin.

Magnus Bjørndal, when he painted the dire consequences of failure to join up with the technical society, obviously did not wish to have his words interpreted literally. His was a species of sales talk. He wrote at a time when the depression of the 1930's was beginning to be felt; when young men, if they weren't losing faith in America's future, were at least discouraged and worried. More than anything else they needed to "get out" of themselves, to stop brooding and join in the social activities that could be enjoyed at small cost in the clubrooms of the society. Furthermore, his remarks were addressed to those who would not seek associations outside their own group. If he intended more than this he was mistaken. Many Norwegian engineers who have never affiliated with Norwegian-American organizations, either with those of old standing or with those of their own making, have nevertheless developed quite normally and are anything but the frustrated misfits that Bjørndal describes. Quiet and modest they tend to be, but they are also socially well-adjusted, have well-integrated personalities, and give evidence at every turn that they too have retained much of the best in their European tradition.

It is important in this connection to make a statistical analysis of the records. The writer has in his possession several hundred carefully prepared "case studies" of the engineers. Of these,

fifty have been selected at random and examined with a view to determining transitional tendencies. Thirty engineers thus chosen have participated actively in Norwegian and Scandinavian non-technical organizations, more often than not in several of them. Twenty-six have been members of Norwegian-American technical societies. More significant still, thirty-two of the fifty are married to Norwegian-born women, three to Swedes, one to a German, and one to an Englishwoman — a total of thirty-seven whose wives would inevitably contribute a European atmosphere to the home. Naturally, Norwegian is spoken in many of the families as well as in the clubs and societies, though not in either case to the exclusion of English. As time passes, English is used more and more frequently in both.

Thirty-one of the fifty engineers have participated in several non-Norwegian organizations. Most of the engineers of any standing belong to one or more of the leading American engineering societies, such as the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the like. While their loyalty to such groups is inevitably greater than to non-professional organizations, they are also enrolled in fraternal, political, and cultural societies of all kinds — a somewhat surprising fact when one considers that an engineer is forever moving about. This tendency, interestingly, almost equals the tendency to enter into purely Norwegian-American activities.

The vast majority of the engineers were born into the Lutheran or Norwegian state church. Only seventeen, however, listed Lutheranism as the religion of their conviction. Of the remaining ten who have church affiliations, two are Methodists and two are Presbyterians; two are vaguely Protestant, one is a Theosophist, one a Unitarian, and two belong to the United Church of Canada. Reasons for non-affiliation or changed membership range all the way from complete indifference to a preference for "American" churches. In the matter of citizenship there is no such variation. Forty-four of the fifty are citizens

of the United States, one has taken out his first papers, and four (who live in Canada) are British subjects. Only one engineer, for reasons that are not clear, refused to become a citizen of this country.[28]

Much unnecessary confusion has been introduced into the immigrant story because of a persistent myth: that life in America is fundamentally different from life in Europe. This myth not only overlooks the fact that American civilization is European in origin, but it also assumes that there is no interchange of influence between countries and continents. In actual fact the town dweller of western Europe finds more that is familiar in the American city—among people of his own class—than is commonly supposed. What is new he quickly learns; even linguistically the educated Scandinavian is far from helpless, and in a surprisingly short time he acquires a sure command of English as well as an easy familiarity with the new folkways. Speaking quite generally, he has more to contribute than to lose, and he represents a gain that has never been fully appraised by American writers. More specifically, the engineer born and educated in Norway (or elsewhere in western Europe) would actually feel less completely at home in a rural Norwegian-American community than he does in an American city, where most of his contacts with fellow countrymen may be reserved for after working hours. Nor does he suffer in any marked degree from the feeling of social insecurity which commonly attaches to the rural or working-class immigrant; his reverence for what might be called the superficial trappings of American life is consequently less profound than is the case with the uneducated.

It is natural, therefore, that the engineer, though preoccupied first and foremost with professional matters, should have turned automatically to the Norwegian-American social life that he

[28] This information is contained in questionnaires that were mailed to and filled out by engineers. Since addresses and preliminary "leads" were obtained from the technical societies, the percentage of those questioned who belong to Norwegian-American organizations is probably higher than that obtaining generally among the Norwegian engineers.

found awaiting him on his arrival in the American city. Coming from a country with a pronounced national consciousness, he went even further and organized new societies that were at once alumni, professional, cultural, and social organizations. Despite the perambulatory nature of engineering, he took his place in the common life of America, assumed the responsibilities that go with citizenship, and became in time distinguishable only by the Old World aura that clings to the person and home of the European who has taken root in the United States.

TOWARD A SOCIAL PHILOSOPHY

NO social philosopher has subjected American economic life to quite so searching an analysis as has Thorstein B. Veblen. Sooner or later the student of the social sciences comes face to face with one or another of Veblen's penetrating observations, and, whether he likes it or not, is forced to accept or reject here a major premise or there a startling conclusion. The influence of Veblen on present thinking is attested by the growing popularity of his theories and by their development, with modifications, at the hands of others.

For our story it will suffice to say that Veblen interpreted our economy, not as a system of capitalism in the sense in which the classical economists viewed it, but purely as a price system. Because of inherent weaknesses, this economy could not hope to survive for long. In a manner almost irritatingly vague, Veblen predicted that a new order would succeed the present one, after a succession of crises, each more acute than the one before, gave proof that adjustment was out of the question.[1]

In Veblen's own words, "Under the rule of the current technology and business principles, industry is managed by businessmen for business ends, not by technological experts or for the material advantage of the community. And in this control of industrial affairs the smaller businessmen are in great part subject to the discretion of the larger."[2] The industrial system, he wrote in *Engineers and the Price System,* is handicapped by

[1] See Joseph Dorfman, *Thorstein Veblen and His America* (New York, 1934), and Alvin Johnsen's brief account of Veblen in *Encyclopaedia of the Social Sciences,* 15:234 (New York, 1935).

[2] *The Instinct of Workmanship and the State of the Industrial Arts,* 351 (New York, 1937). Published by the Viking Press, Inc.

"dissension, misdirection, and unemployment of material resources, equipment, and man power, at every turn where the statesmen or the captains of finance can touch its mechanism." Both direction and investment are "allowed to decide matters of industrial policy which should plainly be left to the discretion of the general staff of production engineers driven by no commercial bias."

The industrial system, with its increasing complexities and many interrelated processes, was, he believed, "approaching a critical pass, beyond which it will no longer be practicable to leave its control in the hands of businessmen working at cross purposes for private gain, or to entrust its continued administration to others than suitably trained technological experts, production engineers without a commercial interest. What these men may then do with it all is not so plain." For the time being, however, the captains of industry and finance continued to "commercialize the knowledge and abilities of industrial experts and turn them to account for their own gain," since "the use of these technologists [is] indispensable to the making of money." As for the engineers, the older generation had "become pretty well commercialized" because of a "long and unbroken apprenticeship to the corporation financiers and the investment bankers," and so they still "see the industrial system as a contrivance for the round-about process of making money." Many of the younger technicians, Veblen believed, were "beginning to understand that engineering begins and ends in the domain of tangible performance, and that commercial expediency is another matter."[8]

While it was Veblen who gave classic expression to the status of modern engineers under the profit system, he is not alone in calling attention to their position of dependence. In the *Encyclopaedia of the Social Sciences* we read:

The increased importance of engineering for production has not been accompanied by a corresponding increase of influence of the

[8] These quotations are from the chapter "The Captains of Finance and the Engineers," in *Engineers and the Price System,* 52–82 (New York, 1936). This book was written in 1923, and reprinted in 1936 by the Viking Press, Inc.

engineer in production, society and politics. The engineers' attention is concentrated upon technical progress rather than upon the conditions requisite to economic success. . . . Only a few engineers become captains of industry and of these only those who have an insight into the problems of economic organization and finance. Singularly few engineers become great political leaders. The great mass of technical functionaries constitute but a passive element in the whole complex structure. . . . The average technician, even when expertly trained, is more easily replaced than . . . a foreman.[4]

That all the engineers are not satisfied with this arrangement is indicated by Stuart Chase's comment, "As a matter of cold fact, many technicians do not hesitate to affirm that they could do better work if they were not constantly impeded by the profit motives of business men."[5]

Stuart Chase wrote in 1929, and Veblen even earlier. It was the depression of the 1930's that led to a more generally critical study of our economic institutions. One of the many proposed panaceas was the movement of the early 1930's known as technocracy. Veblen, in his *Engineers and the Price System,* had stressed the gulf between what we are capable of producing under the efficient direction of engineers and what we do in fact produce under the rule of the captains of industry. The technocrats began where Veblen left off, dealt harshly if vaguely with the use of money in exchange, and emphasized the potentialities of automatic processes as a means of obtaining the desired efficiency. A popular note was injected into the discussion with the hint that all disagreeable hand labor might thus be eliminated. Shrouded in secrecy, the technocratic movement, esoteric though it was, first fired the public imagination, caused much uneasiness, then died out almost as suddenly as it had begun.[6]

What to Veblen had seemed desirable but somewhat remote has actually come to pass, though in slightly different form, according to one contemporary writer. In 1941 James Burn-

[4] Emil Lederer, "Technology," in *Encyclopaedia of the Social Sciences,* 14:555 (New York, 1935). By permission of the Macmillan Company, publishers .

[5] In *Men and Machines,* 335 (New York, 1929).

[6] See Myron W. Watkins, "Technocracy Movement," in *Dictionary of American History,* 5:236 (New York, 1940).

ham published his much discussed *Managerial Revolution,* a book which flatly states that we are already in mid-passage from capitalism to a "managerial society." Production for profit is fast giving way both to state enterprise and to the manipulations of production for purposes other than that decried by Veblen. In politics all important decisions are made by the heads of executive bureaus and commissions—not by legislative bodies; in industry the manager ("operating executive," "plant superintendent," etc.) has replaced the private capitalist of the past. Though they do not *own,* the administrator and manager direct and determine, and as a consequence collectivism and social aims are fast replacing individualism and private profit. A new and dominant aristocracy, according to Burnham, has come into being.[7]

II

Before considering the attitude of the Norwegian engineers to the ideas of men like Veblen, it would be profitable to examine in a general fashion a few of the modern trends and characteristics to be found among the engineering profession. It is desirable, too, to note the differentiation which attaches to the foreign-trained engineer group.

The nineteenth-century engineer, as one American writer has observed, was a kind of "private practitioner," whose work took him from place to place and permitted him a considerable measure of independence in the choice of a job and its execution. Quite commonly he opened a consulting office as would a doctor, lawyer, or dentist. The competitive nature of his professional life and the climate in which he developed contributed toward a genuinely individualistic outlook and a social philosophy not unlike that of the businessman in the same period. Today, by contrast, over 95 per cent of the engineers are employees, usually of a large engineering firm or industry, or the government. This change, a corollary of the trend toward concentration that characterizes all our economic life, has been

[7] An excellent condensation of Burnham's theory is found in his "Coming Rulers of the U. S.," in *Fortune,* 24:100, 119, 122, 124 (November, 1941).

greeted by frequent complaints that the engineer now enjoys less freedom than the professional man in the legal or medical fields. Salaries have tended toward uniformity, with ceilings at the top and floors at the bottom; the inevitable result has been that earnings of the gifted men have been shrinking and the opportunity to amass fortunes has largely passed. The question has also been raised, as it has been raised in connection with our productive equipment, whether all technical ability is being efficiently utilized—whether the security and economic gain at the bottom of the ladder have not been won at the price of restraint and limitation at the top.

Counteracting this trend toward dependence and uniformity is the fact that more and more positions are being filled by technically-trained men, both in private and in public life. As business assumes the corporate and large-scale form, it also requires of those who direct it an ever-increasing knowledge of the technology that has come to be its primary characteristic. Out of this need, as Burnham points out, is developing a managerial and planning class. Nor need the engineer cast longing glances at the situation of the doctor and lawyer, for the independence of these men is today largely illusory; both in medicine and in law the trend is toward concentration—in the clinic, socialized medicine, the law firm, and the business corporation. It is precisely in industry, with its many new opportunities, that the future of the engineer lies. "The extravagant prophecies that were once heard of limitless possibilities may not . . . be fulfilled, but engineering appears capable of offering an interesting, productive, and relatively remunerative career to an increasingly large number of men."[8]

A study made by the Russell Sage Foundation reveals that in 1924 engineers five years out of college were earning a median income of $2,860; ten years after graduation they could expect $4,000; after fifteen years the salary rose to $5,000; those who had graduated thirty years before were enjoying median

[8] Esther Lucile Brown, *The Professional Engineer*, 85 (New York, 1936). The conclusions made in this volume, p. 81–86, have been drawn on liberally for the foregoing section. This book was published by the Russell Sage Foundation.

earnings of $7,500.[9] This survey, while not entirely satisfactory for present purposes, nevertheless indicates that the earnings of engineers in recent times are adequate for a comfortable standard of living but that, with exceptions, they are not munificent.

The engineer, when compared with representatives of other professions, is frequently accused of being narrow, interested only in detailed technical work. He has little understanding, the argument runs, of the economic forces that operate in industry; he is not a man of broad culture; he fails to measure up to the demands of a managerial position; and, finally, in neglecting his obligations to society he reveals an appalling absence of social responsibility. Inevitably the causes are found to lie in the engineer's courses of study. His education, it is frequently remarked, is of a predominantly undergraduate nature. Unlike the doctors and lawyers, the engineers enter the professional school without preliminary preparation in the liberal arts. The consequence is a schedule overcrowded with technical courses to the exclusion of work in the humanities and the social sciences.

Engineers are themselves conscious of the shortcomings of present technical education and there are some indications that they are moving toward the ideal of the engineer as a leader of men rather than as a highly specialized agent of the business interests. This trend is reflected in the recommendations of the Society for the Promotion of Engineering Education and in the discussions that are increasingly frequent in the technical journals. Greater emphasis is already being placed on the study of administration, economics, sociology, and political science, and there is a wide-spread interest in subjects that are loosely designated as "cultural" or "broadening." Influence is being widely exerted to lengthen the course of training from four to five years and to encourage the better students to take up graduate study.

Whether or not a mere juggling of college courses will affect

[9] Brown, *The Professional Engineer,* 70. To the present writer these figures seem unexpectedly high.

the general outlook of the engineering group remains to be seen. It is obvious that altered courses of study as such are meaningless without a corresponding change in the philosophy of the engineering college. It is unfair to accuse engineers and scientists alone of a "complete isolation from the economic and social world," as Henry A. Wallace has done, at least by inference; but he is on solid ground when he says that "the emphasis of both engineering and science in the future must be shifted more and more toward the sympathetic understanding of the complexities of life, as contrasted with the simple mathematical, mechanical understanding of material production."[10]

III

When we turn from the American engineer as a general type to the engineer of foreign birth and training, we find that the same generalizations apply. But there is a considerable element of variation.

The graduate of Trondhjem, Bergen, Christiania, Horten, or Porsgrund who arrived on American shores during the eighties or nineties of the last century and the early years of the present one came in response to a need for specialized skills, and he regarded America as the land of limitless opportunity. He had youth, ambition, college debts, and a sound theoretical training as spurs or aids to the realization of his dreams. Though he invariably sought employment with established firms, he looked forward to an independent career once he had passed through the period of apprenticeship and acquired competence in a certain field of engineering.

In treating of the careers of the more gifted engineers, our story has been an almost monotonous record of dependent positions followed by consulting practices, partnerships, exploitation of inventions, manufacturing projects, and the like. Not infrequently this rise to independence and professional recognition was accompanied by the acquisition of considerable wealth. Even in the many cases where an engineer retained

[10] Quoted in Brown, *The Professional Engineer*, 20. See also her discussion of engineering education, p. 15–21.

his connection with a private or public concern, he commonly became chief engineer, director, or in some other way gained a voice in policy-making as well as responsibility in executing plans. Such a person naturally accepted without serious misgivings the major tenets of individualism. In politics he was invariably Republican, in his social philosophy conservative, and, however strong his professional loyalties, he had no exaggerated notions of the part an engineer should play in the life of the community. All in all, he was content with things as he found them, and he lived out his days in a milieu largely undisturbed by the problems of today.

One of the questions most frequently asked of the engineers by the present writer is this: To what extent did the fact of your foreign training work to an advantage or disadvantage in your professional life? In a majority of cases the older engineers answer that they did not feel discriminated against because of their origin, and many insist that it was at times a positive advantage—as it is with the artist today. They are convinced that their education was superior to that of many of their native-born associates, who frequently were helpless in the face of a simple theoretical problem.

They are usually quick to add, however, that the American-trained engineer had a stronger aptitude for business, administration, and the purely practical aspects of engineering, and was less inclined to become lost in the details of a project. Occasionally the same men complain that the foreign-trained engineer has a stronger tendency than the native to remain in strictly technical work. Almost all of them were convinced that the immigrant must work a little harder to overcome the initial barrier of language and to acquire a mastery of American techniques; furthermore, he must rely almost exclusively upon his own abilities, since he rarely has the advantage of family or other personal connections in the offices of those who own and control.

When one turns to the younger engineers, the answers are different. The friendliness toward foreign skills is notably cooler

today than it was, say, thirty, forty, or fifty years ago — just as the demand for foreign technical skills is less than it was before the American schools attained their present numbers and standards. One often hears remarks such as these, "The foreign-born are discriminated against, but they are better trained." "European education is broader and more thorough, but these facts are not generally recognized." "Scandinavian engineers who are willing to work hard to overcome the language handicap have a distinct advantage over native Americans, since their education is superior, they work harder, and they owe their positions to ability alone." "The handicaps of the foreign-born are not so noticeable in good times; generally in hard times they must be so good in their work that the economic advantage of retaining them is apparent." "We are at a distinct disadvantage, especially in times of political unrest and social instability, and the situation gets worse rather than better." "The handicap is noticeable only in sales and public contact work." "There seems little opportunity of rising to responsible positions." "It is harder for the foreigner to reach the higher job brackets." "Native engineers are promoted ahead of the foreign-born." "There are too many 'fathers' sons' in high positions."

Remarks of this kind are too numerous to ignore, though it would be a mistake to assume that they represent a generally negative attitude. It would be interesting, too, to question the same engineers twenty-five years hence. Many are now struggling up the ladder of professional recognition, and success in their case, as with older engineers, will no doubt change their point of view. It may be true, as one engineer has put it, that "There are just as many successful foreign-born as native engineers — on a percentage basis."[11]

The answers to any question put to the engineers seem at first as varied as the individuals themselves. Yet when subjected to the test of numbers, the replies fit into a fairly clear

[11] These quotations, slightly edited, are taken from questionnaire sheets in the writer's possession.

if irregular pattern. They reveal, for example, that in the matter of salary, the differences between the native and foreign-born are slight—for the same type of work.[12] Certainly the opportunity for making great fortunes is less today than it was in the nineteenth century. The widening field of employment, often leading to positions of a responsible nature, is also clearly discernible.

In the field of political affiliation the shift is unmistakably from Republican to Independent or Democrat, usually of the liberal or New Deal variety. The shift is due as much to the growth of collectivist democracy in the homeland as to the growing sense of social responsibility among professional people in America. The young engineer who came from Norway during the 1920's would find it as natural in the 1930's to accept the program of the late President F. D. Roosevelt as it was for the immigrant of 1890 to embrace the more conservative and individualistic doctrines of the Republican party.[13]

IV

Since the pressure in America—as earlier in Europe—is toward expanding the education of engineers, the writer has been impressed by the opinion of some Norwegian engineers that the training should be briefer and limited to strictly fundamental matters. The most convincing exponent of this theory is Anton Grønningsæter, the metallurgist. Speaking before fourth-year students of mining and metallurgy at Toronto University, he recently remarked:

> I believe it would be an advantage to get a clearer view than today of the proper division of . . . training between the Universities and

[12] A word of reservation is necessary at this point because of the inadequacy of figures for the engineering profession in general and the understandable hesitancy among those directly consulted to give full information about their incomes.

[13] It is significant in this connection to note an almost total absence of fanaticism on the part of either "conservative" or "liberal." The Norwegian engineer in the truest sense is a "moderate," characterized by a striking independence of thought. Of thirty engineers selected at random and without regard to wealth or age, thirteen are Republicans (two of the liberal kind), seven call themselves Democrats, six prefer to be known as Independents (three with left-wing tendencies), two call themselves Liberals, one has "Republican leanings," and one is "mildly conservative." Only one Republican indicated membership in Gannett's Committee to Uphold Constitutional Government, an extremely conservative group.

industry; at the present, my impression is that industry is expecting too much from the Universities and too little from itself. In general, I believe the regular universities should attend to fundamentals and principles, while special postgraduate schools and individual industries should attend to the specialized training of the graduates needed for a particular field. . . . The graduate should realize that his first years out of school should largely be considered as continued education.[14]

Addressing the Oslo branch of the Norwegian Engineers' Society in 1940, Grønningsæter outlined methods whereby the preparation of engineers at Norway's Institute of Technology might be improved. There should be, he insisted, a greater emphasis on languages, especially English. Students should also learn to know workers, their living conditions and psychology, by taking work as laborers during vacations. Too many people demand specialized knowledge on the part of the graduate, whereas the greater need is for a thorough general preparation on which to build in later years. Work under experienced engineers, postgraduate study in certain instances, and the job itself will provide the necessary specialization; one's whole life, he added, is a continued schooling. By fundamental courses he meant mathematics, mechanics, physics, general chemistry, physical chemistry, and the like. Students should learn to use handbooks, periodicals, and other sources of information rather than seek to remember all facts. One later learns in his specialty all that is needed in the matter of details; the rest he has no use for. Lectures should be brief and crystal-clear.

Grønningsæter, himself widely read in the economic and social fields and eager that the institute should stress the significance of these and related branches of knowledge, nevertheless maintained that it "is not the duty of the Institute to train businessmen, economists, politicians, and directors." Even so, the students must acquire some of the skills of each of these professions in later years. While opposing the lengthening of the course of study, Grønningsæter favored a year of graduate study, preferably abroad and in America, giving as one of his

[14] From a copy of this speech made available to the writer by Grønningsæter.

reasons the present superiority of English-language technical writings over the German. He also called upon industry to assume increased responsibility for continued training of engineers, foremen, and workers.[15]

Other engineers of sound judgment and professional recognition have maintained—sometimes with considerable heat—that the present engineering course, both in Europe and in America, is far too prolonged, and that the graduates of Norway's Institute of Technology are older than they should be when they enter the technical professions; they point to the amazing adaptability and skill of the men of Horten, Porsgrund, and of the schools at Trondhjem, Bergen, and Christiania. Their training was in fundamentals and they became specialists on the job, not before. The graduates of Norway's leading technical colleges lacked one thing in their training: practical demonstrations to supplement theory. Whether they would be able to compete today with the same success as before is purely conjectural, but it is significant that not all professional men favor the trend toward specialization in education and the ever-lengthening period of preparation.

Engineers themselves will debate for hours on end and never arrive at a solution of the problems posed by mention of education, the differences between native and foreign-born, politics, and the changing status of the engineer in the present century. About their permanent place in society, however, there can be no argument. In the first chapter of this study, sufficient evidence is given to indicate that most of the engineers of our story came from the homes of the middle class—merchants, lawyers, doctors, engineers, pastors, government functionaries, sea captains, and moderately well-to-do farmers. Their children in America, invariably college-educated, are entering the fields of business and the professions. With hardly an exception, the

[15] "Kan ingeniørutdannelsen ved Norges Tekniske Høgskole forbedres?"; a lecture delivered February 23, 1940, and summarized in *Morgenbladet*, February 24, 1940. It is interesting to note that Professor Sem. Saeland, physicist at the Norwegian university in Oslo and first president of the Institute of Technology, was himself completely convinced of the value of a general technical education.

personal data on the Norwegian engineers tells an obvious but significant story. One has two sons and a daughter; the sons are studying to be engineers, the daughter to be a dietician. Another has one son and a daughter; the son is a dentist and the daughter, a college graduate, has a supervisory position in an engineering office. A third has four sons, all of them engineers. Another has one son, a lawyer. Still another has a son studying at a state university for a business career. Government service, usually by way of a specialized profession, is a common occupation. It need hardly be added that these second-generation Norwegian Americans live almost entirely in the cities, are widely diffused in the larger American population, and will therefore quickly shed any slight Norwegian coloring that may now attach to them. And it is reasonable to assume that they will adopt the moderately conservative social ideals of the educated middle class in American society.

V

The close connection of the engineer with production and labor and his strategic position for studying the social implications of modern industry should make him uncommonly sensitive to current problems, if not indeed a leader in their solution. How does the Norwegian engineer in America react to this responsibility—and what, more specifically, does he think of Veblen's theories?

For the most part those who have expressed themselves as to the engineer's proper role in our economic and social life feel that his influence should be greater than it is now. Characteristic of the many statements in the "case studies" is this: "He should be a leader in business and in politics, which so influence the economic life. But the fault has been his own; he has not been the kind of citizen that his close connection with production and labor would seem to make logical and natural." Another sees no reason why the engineer should not more frequently assume administrative positions in business life. A third feels that the engineer's training is at fault, since it has

led to abstract thinking, an overemphasis on details, and slowness in arriving at decisions—but that the engineer has a soundness of judgment that would be of great value outside as well as within the technical field. Only one, or possibly two, of the many who were interviewed professed absolute faith in the vague tenets of technocracy.

A large number were of the opinion that engineers should stick to purely technical activity, aim at research leading to cheaper production and improved quality of goods. While some were convinced that the engineer should interest himself in politics, about an equal number were deeply prejudiced in the matter of anything concerning the politician and his difficult tasks; they were inclined to feel that more good could be accomplished by remaining in the background and working out problems in the office than by mounting the speaker's platform. This did not, in the opinion of some, rule out a growing importance of the engineer's place in industrial development, public works, and better utilization of our resources.

Selected comments from the majority who favor a more active part in the larger life of America are of sufficient historical interest to merit recording: "There are unlimited possibilities if the technicians as a body would only give their insight and knowledge to the humanitarian solution of the great problems confronting us and the world." "With his training in planning and organization, the technician should fill more high positions . . . many positions that are now filled by lawyers." The engineer should "streamline our system of distribution so that it would be up-to-date with the system of production which engineers have already streamlined." "His thorough training and analytical mind should qualify him as a servant in various public offices. He should have free hands to carry out his responsible tasks with the highest standards of ethics." "Though his part should be a bigger one, not every engineer is up to the task. Some are introverts or too preoccupied with technical problems. There is only one engineer in the New York State senate [*in 1941*]. The lawyers play far too

important a role in this industrial age." "Besides the role he plays today, he should and will be playing an increasingly dominant role in the economically *planned* society of the future." "The technical training of the engineer should be utilized more in political life; but the contrast of political intrigues and manipulations is too great to make politics attractive to the majority of the engineers. They should certainly be able to help materially in reducing the appalling waste in our political life and in the economy of our communities." "The engineer, to play his proper role, should have a more liberal education." "The engineer should make this a more pleasant, convenient, and comfortable world to live in."

Of the many who favor a more active and varied participation on the part of the engineering group, not a few express misgivings concerning its educational and other qualifications. An outspoken minority, composed largely of men who have been successful as managers or business enterprisers, go much farther. "The technician," one of them insists, "has a somewhat exaggerated opinion of his role in our economic life. The fact that he has an *active* part in production makes him feel that he is entitled to a *leading* part. This does not follow, as the technician's necessary devotion to detail, which is essential for the technical accomplishment, at the same time makes it difficult for him to bargain and compromise and cheerfully see the other's viewpoint."

In somewhat the same vein but with a note of regret, another writes: "[The engineer] is necessarily a hired man, working for so much per month (as little as possible) although he *may* have a far better brain, more inventiveness and initiative than the men who hire him, while the latter go off with the big prizes because *their* ability is to garner money, while *his* is to create goods or equipment for producing goods. . . . I am not talking about those few technicians who are also good businessmen at the same time; the latter should have the management of factories, but the average technician is generally poor at marketing and distributing the goods." An otherwise liberal engineer

adds this: The technician should "stick to his job unless especially gifted or qualified for other work," and another concludes, "I am not in agreement with the assumption that a technically-trained man must be a success in other lines simply because he is an engineer."

In discussing the larger role of the engineer, our group has indirectly expressed its attitude to the views expounded by Veblen, particularly in his book *The Engineers and the Price System*. A distinguished midwestern engineer, asked for his opinion of this work, replied:

I agree in what the engineer some day in the future may be called upon to do. But I also believe [he] will not lend himself to any undertaking of that sort until a complete collapse of the existing economic order has taken place, and perhaps not even then unless a strong hand puts him to the task. Today's engineers do not stick together. Their interests are as selfish as anybody's and they are to a great extent willing to sell their services to the highest bidder for almost any task within the law. There are very few independent engineers and their views seem always colored by their fear of losing a job or a client. And the older a man gets, the worse it is for him to disagree. This applies to foreigner and native alike.

Far less friendly to Veblen is the statement of a prosperous engineer-manufacturer in the East:

The trouble with Thorstein Veblen . . . and a host of others is that they have buried themselves in books too much and have been out of contact with actual life. None of these gentlemen . . . has the faintest idea of how industry is operating today. This detachment . . . has caused such leaders . . . to stray into impossible and impractical and outright stupid conclusions. Expert management in industry is today in practical operation all over the world and has been for several hundred years. By that I certainly do not mean to say that only engineers are running industry or that they should ever do so. As a class, engineers have no more business sense than any other class of average people. They would certainly make a mess of it if they were to run an industry without the aid of the general businessmen of whom Thorstein Veblen has such a low opinion. The general businessman is today quite often much more of an expert in his field than any engineer and there is no question in my mind that he is just as valuable to the industry, if not more so, than the engineer. . . . It takes all kinds of people to make a world and there certainly is no class of people developed as yet that knows

how to run and manage the affairs of other people better than they themselves can do it. . . . Economic activity can only be developed to its highest state through the profit system and through free individual enterprise.

That the Norwegian engineers have often earnestly discussed among themselves their status in society is apparent when one pages through the volumes of their *Journal*. Thus we find, for example, an article by Kyrre Eide titled, "Social Leadership, Should Engineers and Scientists Take the Lead?" Eide, who maintains that science and politics cannot be separated, does not in this particular paper, however, go far beyond urging membership in the Norwegian-American Technical Society as a first step toward social leadership.[16]

The engineers, like all other wage and salary groups, are interested in obtaining higher incomes and improved professional status. Typical of the many discussions centering about this subject is one divulged by the minutes of the Chicago Norwegian Technical Society.[17] J. Haakon Hoff, who, like Giaver, worked hard in the interests of the engineers, spoke on the subject, "How to Increase One's Salary for the Benefit of the Individual and to Foster Respect for the Engineering Profession in General."

Drawing on his rich experiences, Hoff stated that as he climbed the ladder of technical positions following his arrival in America in 1888, he never received an increase in salary without having to ask for it. He was of the impression that engineers were neither as fully respected nor as well paid as other professional men, and that the public generally must be educated to appreciate their value to society. Advising his hearers to move when possible into the business phases of their profession and to be alert to better income opportunities, he concluded that employers and public alike would be better served if salaries were higher. In the discussion that followed, one member proposed a union of engineers and draftsmen. On

[16] Vol. 11, no. 2, p. 13 (December, 1938).
[17] October 20, 1925.

this occasion, as at other times, the proposal to identify engineers with the laboring class, and thus to bargain for better wages and working conditions, had no measure of success whatsoever.

Several years later, in 1928, Hoff believed that the times were favorable for structural designers and engineers. Restricted immigration and the shortage of competent men in America had created a situation that was not to be ignored. Graduates of American engineering colleges, discovering that the profession was underpaid, were entering other fields. Employers, he said, "know so little about an engineer's qualifications, that they all look alike to them. Instead of keeping [the engineers] and working them into their business . . . they hire them and fire them like laborers, and this alone, of course, encourages . . . especially the better men, to go into other occupations." The field is thus to a large extent left open to foreign engineers, graduates of correspondence schools, and practical engineers who have worked up from the drafting room. The Norwegians therefore need not be concerned about competition. They should take advantage of the good times, demand more pay, and, except in unusual situations, refuse to work overtime.

This line of argument closely resembles the reasoning of the labor union, and one wonders why the principle of organization should be so abhorrent to professional men — engineers as well as others. The answer is given, at least in part, by Hoff himself, "We should all be thankful that we are here in this wonderful country with the many opportunities it gives us."[18] Reasons not given are the prejudices of the class to which engineers belong and the domination of the technical profession and its societies by older, conservative members and by industry. It is possible, as a recent writer has expressed it, that proper organization in the interest of engineers must come about by an evolutionary process.[19]

[18] "Opportunities for Norwegian Engineers in the United States," in *Norwegian-American Technical Journal,* vol. 1, no. 1, p. 13 (February, 1928).

[19] John Mills, *The Engineer in Society* (New York, 1946). See especially "Organizing for Evolution," p. 129–140.

VI

When we turn from the group and its problems in modern society to individual representatives who were students of economic and social life, we find a few engineers who have made worthy contributions. Two men, each for a different reason, have dealt with economic problems on a level sufficiently above class prejudice to merit more than casual reference to their published writings. They were Alfred Alsaker and Anton Grønningsæter.

The first of these men, Alfred Alsaker, was chief engineer in charge of drafting and sales for the Delta Star Electric Company in Chicago at the time of his accidental death in 1936. He was a graduate of Bergen's Technical College who came to America in 1905; he was keenly interested in social and cultural activities; he served as president of both the Norwegian-American Technical Society and the Chicago Norske Klub, and was known for his fair and logical mind.[20] Before his death, at the age of fifty-one, he had completed a book, *The Capitalistic System and the Nature of Unemployment*, and arranged for its private publication.[21] Unique among studies of unemployment, Alsaker's analysis is based upon several fundamental mathematical equations; it proceeds therefrom with a contagious optimism and faith in the potentialities of capitalism, once the problem of unemployment is handled justly. In his preface Alsaker informs us:

> After the crash in October 1929, economic problems became most active subjects of discussions. I was often puzzled by the astonishing confusion of thought on economic questions even among my friends in the engineering profession who by their accomplishments had proven themselves to be men of more than average ability. . . . During one of these discussions I conceived the idea of analyzing the *general behavior* of the capitalistic system by the method commonly applied to engineering problems: First define the measurable economic quantities that have a pertinent effect on the operation of the system and, secondly, establish their mathematical relationship if any.

[20] See *Norwegian-American Technical Journal*, vol. 10, no. 1, p. 7 (February, 1937); *Scandia*, August 6, 1936; *Skandinaven*, August 7, 1936.

[21] The Pioneering Publishing Company, Oak Park, Illinois, 1936.

It is interesting to note that Alsaker fully expected his analysis to "prove the capitalistic system to be inherently unstable and detrimental to the workers' interests. This expectation was based upon studies made in my younger days when I had come to the conclusion that the capitalistic system was obsolete and ready to be replaced by a planned economic system." As his book amply demonstrates, this expectation was not fulfilled. He explains:

> I had neglected to search beneath the surface for an explanation why a seemingly helter-skelter system should work at all. I had failed to realize that by the very fact of its continued existence the capitalistic system must by necessity contain within itself an automatic stabilizing force of some kind. Actually my analysis resulted in equations showing that the capitalistic system is like an exceedingly interesting, complicated and self-regulating machine. Not an old thing in process of dissolution, but a young institution, considering its ultimate objective. Not an enemy of labor but a system whose very existence depends upon continually increasing the workers' standard of living.

In the idealized system of capitalism, according to Alsaker, the prime mover is the desire for profit-earning wealth, which in turn provides economic security, power, and independence in old age. Since capitalism is a dynamic institution, the average total production of goods must increase, even if the population becomes static. "The rate of increase in production wealth must conform to the rate of increase in the consumption of goods and services," since it is impossible for "workers and capitalists to save more from the processes of production than the total amount required for new investment goods." Any excess of savings beyond the needs of capital investment "becomes idle money and results in unemployment to the extent that the total rate of consumption of goods by all the unemployed is always equal to the total rate of idle money-income."

Unemployment, Alsaker maintains, sets in when an attempt "is made to use money or credit as a medium for storing wealth, and the system automatically frustrates such attempts by causing unemployment to the extent that the purchase price of the goods consumed by all the unemployed is equal to the idle

money-income stored by others." Although it is impossible for the economic unit as a whole to bring about such a maladjustment, it is quite "possible for certain individuals to do so and it is those individuals who cause workers to lose their jobs resulting in loss of property to both workers and capitalists." The responsibility for the tragedy of devaluation, bankruptcies, and the transfer of property from the unemployed to those only slightly affected by the depression must rest squarely on the shoulders of those who disturb the natural equilibrium of our economic life.

Since it is what Alsaker calls idle money-income that causes unemployment, he proposed an optional unemployment tax on surplus income. The effect on unemployment would be the same whether taxpayers delivered the money to the government or bought consumers' goods for themselves, for in either case public works or private employment would result. The important thing is that "the owners of idle money-income should be compelled to pay the cost directly." Even without such a tax the self-regulating capitalistic system would "gradually and automatically" eliminate both idle-money income and unemployment by "increasing the workers' consumption rate and by reducing the income to capital without destroying the incentive to acquire profit-earning wealth."

But Alsaker, the humanitarian, was eager to avoid injustice and hardship to individuals who during periods of deflation are unemployed through no fault of their own, who quickly exhaust their meager savings, and whose needed consumption of goods must be financed by others. The "duration and intensity of deflation periods can be limited and unemployment practically eliminated by providing work for the unemployed, financed by an optional unemployment tax on surplus income." The capitalistic system would be further improved, in Alsaker's mind, by "gradually eliminating income from parasitic investments, by gradually divorcing the . . . government from all economic activities that can be run by private capital." Finally, when the consumptive capacity of the workers has approached

the point of saturation, the government should institute "a system of old age annuities through which the active workers would support the aged and disabled workers at their accustomed standard of living. The operation of the system would then approach the operation of an Ideal Capitalistic System," which he believed fairly easy to attain.[22]

Despite his engineer's approach, the use of analysis based on mathematical equations, and his spirited defense of an ideal capitalism, Alsaker differs from others only in his *method* of solving what is admittedly one of the greatest problems in modern life—unemployment. It is commonly agreed that depression will eventually generate a period of recovery and that recovery will sooner or later be followed by a new prosperity stage. What any fair-minded economist is concerned about are the human and economic losses inherent in depression and deflation. Alsaker's plan for ending unemployment is best stated in the engineer's words: "Spend your share of the idle money-income or pay it to the State to provide work for those who are forced out of employment when you refuse to use your allotment from the production of goods. . . . You are denied the right to keep workers in idleness. . . . If you cannot use the share you receive from production, the State is justified in taxing away from you, that portion which you are unable or unwilling to use. This share will then be given to the unemployed who can use it."

VII

No less important than unemployment in the consideration of contemporary American problems is the question of the relationship of employee to employer. Full employment and full production are impossible without industrial harmony. That many Norwegian engineers, among them Carl Barth, should have given serious thought to the labor problem, is but natural; no less natural is their tendency to make comparisons between the Old World and the New and to draw upon the long experience of the Scandinavian countries. As in their technical work,

[22] The quotations are from Alsaker, *The Capitalistic System*, 202–207.

so in their social thought; they think in terms of transplanting, where advisable, the progressive measures of the homeland.

Representative of the best thought on employer-employee relations is an address presented before the Toronto branch of the Canadian Institute of Mining and Metallurgy, by Anton Grønningsæter. His paper, "Employer-Employee Relations in Norway," is a modified version of a lecture originally delivered before students at the University of Toronto.[23]

Grønningsæter is impressed by the fact that in America, while much is said about labor unions, very little is heard of a corresponding organization of employers. "I believe," he said, "a strong organization on one side necessitates a correspondingly strong organization on the other side." Familiar with conditions in Norway, "where they have struggled with these problems [*of industrial strife*] for fifty years," he found that the New World was at least thirty or forty years behind Western Europe in the development of organizations to solve industrial conflicts. America now, however, faces much the same situation as Europe, and she must sooner or later set up the machinery needed for the peaceful solution of differences between worker and employer.

In northern Europe, notably in England, labor, during the early stages of the industrial revolution, was at a distinct disadvantage in bargaining; this could be overcome only by the organization of trade unions—first in England and later in the other countries bordering on the North Sea. The organization of labor led, in turn, to the adoption of similar principles of co-operation and majority rule on the part of the employers. In the Scandinavian countries, Grønningsæter said:

> There are now few employers who believe that a final solution to the labour problem in a democratic society can be found independently by the individual . . . employer, by Workmen's Councils, by Company Unions, or by doing nothing. Quite a few thought fascism or nazism would provide the solution, but I expect most of them have changed their mind about that. Labour strongly believes that groups of co-operative unions directed from the outside, inde-

[23] Canadian Institute of Mining and Metallurgy, *Transactions*, 46:97–112 (1943).

pendent of the management, are necessary for a satisfactory protection of labour. The employers have adjusted themselves to the situation, some cheerfully, others perhaps reluctantly resigning themselves to the unions as an unavoidable evil.

They have also come to accept employers' associations as "necessary for an orderly settlement of labour conditions and for protection of industry." The majority of the Scandinavian people have recognized both collective organization and collective bargaining as "justified in our present form of democratic society." Norway, about twenty years ago, tried compulsory arbitration and found it wanting. "It only seems to work under dictatorships." Compulsory mediation, on the other hand, has had a greater success.

Why, more specifically, did the Norwegian employers organize into associations? "It was very soon found that the pressure exerted by the labour unions tended to disorganize a reasonable balance in industry." The only means of restoring the balance was a union of employers. Those who did not join the association soon discovered that the "very aggressive and intelligent Union management" put them "under constant pressure." Grønningsæter, himself for ten years manager of a unionized plant in Norway, knew whereof he spoke:

In the event of a strike, the comparatively few employees of a single plant can be supported by the large membership of a group, or even by the central labour organization, whereas the company has nowhere to turn for help or support. . . . After obtaining . . . strong advantages in a number of individual plants, the Unions use these as arguments for demanding like terms in all other plants. As a consequence, a plant or company staying outside the Employers Association was sometimes looked upon as a "scab," likely to make trouble for others.

More important still is the lack of a general policy toward employees in the absence of effective organization. Labor naturally expects a reasonable similarity in pay for work of the same kind in different industries; an orderly adjustment is possible only when both labor and management form associations.

Recognizing these facts, employers in all of the Scandinavian countries were organized by 1900. Growth in membership was

slow because individual firms were hesitant to join a strike or lockout, "perhaps in another line of business," simply because a majority of the association members voted in favor of such action. Many also objected to subscribing to standard wage rates and working conditions; "quite often the employer was inclined rather to buy peace by paying higher wages than were in force in neighbouring plants." Anyone familiar with the history of trade unionism senses the story, on the side of management, of the reluctant surrender of individual freedom for collective security. But the choice had to be made, for "the final and inescapable consequence of unrestricted individualism is anarchy." In Norway today very few companies remain outside the Employers' Association.

Within each field of production — such as mining, shipping, and the paper and pulp industry — employers combine and maintain a staff to handle disputes as they arise. General policies are determined by a board of directors chosen from the co-operating plants. All such groups, in turn, are united in a central organization which strives for uniformity in wages and working conditions on a national scale. The voting power of the individual companies is roughly proportional to the number of employees on its payroll. The national association maintains a policy-determining central board, an executive committee, and a managing director. In organization and function, the Employers' Association parallels the national organization of labor.

Certain principles and practices have gradually evolved as the products of negotiation between employee and employer. One is the 48-hour week. Another is a two weeks' vacation with pay. Generally speaking, uniform pay for work of one general type is insisted upon by labor, and the employers are equally insistent on maintaining the "open shop" — despite the fact that almost all Norwegian workers belong to a union and pay their fees without argument. Craft unions are regarded by Norwegian labor leaders as obsolete; employers, too, insist on agreements based on industries. Some craft unions have at-

tempted, without success, to exist independently of the Central Association of Labor Unions. According to Grønningsæter, a struggle like that between the C.I.O. and the A.F.L. in the United States "can happen only at an early, undisciplined stage of the development of labour relations, before employers are organized, and there is nothing of that sort in the Scandinavian countries."

Norway's dependence on foreign trade necessitates production costs that permit her to compete in world markets. For this reason the major work of the Employers' Association is the "maintenance of reasonable wage relations as between different industries." The individual employer is protected against added burdens imposed by organized labor just as individual workers are protected by their unions against exploitation. During the long industrial struggle that has taken place in Norway, the union leaders, if not the mass of workers, have come to accept the position of the organized employers, that wages should be determined by what the marginal firms are able to pay.

Collective bargaining, as already stated, has obtained general acceptance in the Scandinavian North. The essential difference between a country like Norway and our own in this matter is that in Norway machinery has been created to facilitate the bargaining process in a manner reasonably fair to both sides in a dispute—and to the public. If a local union, for example, is dissatisfied with its present agreement, which usually runs for two years, it files notice, several months before the old agreement terminates, that certain changes are desired. Representatives of the workers and management get together, discussions follow, and when the two groups are in agreement and their settlement has been approved by the central organizations of labor and industry, a vote of the members of both sides gives final ratification. The local plant must accept what the labor and management groups decide.

If agreement is not reached locally or between the groups, a mediator representing the national government appears on

the troubled scene. If he is successful in working out a settlement acceptable to both parties, the negotiators recommend approval by their organizations; this is usually given. If, however, the members of the rival groups reject the mediator's proposal, a strike or renewed government intervention follows. In the event of a strike, at least two weeks' notice must be given; the strike once on, government intervention again occurs until ultimately agreement is reached.

The fact that most strikes and lockouts are of short duration, however, is due as much to the expert and responsible leadership of labor and management as to the efforts of the state mediator. Grønningsæter believes that the compromise inherent in mediation is bad for union and management discipline alike. Labor in Norway, as elsewhere, is opposed to government intervention. That both labor and management have reached a state of maturity in industrial disputes is evidenced by the fact that strikes are conducted in an orderly fashion by the unions, and owners do not resort to the strike-breaking tactics that have blackened the pages of industrial history. Mediation has been reasonably successful and has served as a necessary step in the evolution of greater responsibility on the part of the leaders of labor and management, and it has worked in the interest of the public.

Grønningsæter, looking back upon his experiences as a manager in Norway, considers that the chief value of labor unions lies in "providing protection for classes of labour formerly paid unreasonably low wages compared to the bulk of labour." Among the "bad" features are an occasional tendency to push wages beyond what technological and business conditions would seem to justify, unlawful strikes, and interference with the general efficiency of management. He qualifies his judgments, however, and readily admits that management all too frequently is to blame for what is commonly considered the doings of organized labor.

Turning the spotlight upon the American industrial scene, Grønningsæter feels that, since conditions here have not as

yet crystallized as in Europe, certain new features, based upon the lessons learned from European experience, may be introduced through legislation to correct existing abuses. These would include "annual elections of Union officials; publication of annual financial statements; and secret, perhaps compulsory, publicly controlled election votes and strike votes. Last — but not least — [they] should if possible make the unions responsible, financially and otherwise, for the sanctity of contracts made for the unions as such and for the individual members." Though Grønningsæter does not here specifically mention management, it is clear from what he says elsewhere that he also favors curbs on industrialists as a safeguard to the public and to the workers.

The Scandinavian countries appear to have made considerable progress within the frame of democracy toward "adjusting labour conditions to the twentieth century industrial society." Here in America it may not be necessary to undergo this extensive evolution; it "should be possible to get a good deal of benefit from this experience and thereby shorten and ease the process" of attaining the harmony which is essential to modern life.

VIII

It cannot be said of any professional group, in America or elsewhere, that in its social philosophy it is very far ahead of the general body of citizens. Engineers — like teachers, doctors, and lawyers — are naturally eager to advance the interests of their group, and wherever possible they like to increase their influence in society. For the most part, however, they are conscious of their opportunities and prefer to work within the frame of the existing order — a system that fixes definite limits to their power but is also becoming increasingly dependent on technically-trained men. It cannot fairly be said that this order, motivated as it is by the drive for profit that Veblen deplored, is unfriendly to the engineer. His grievance, if he has one, is simply that his voice in determining the direction and purposes of production, as well as his remuneration, is less than his importance in society would seem to merit.

In the light of these facts, the Norwegian engineers are not apt to consider themselves fitted for a role in our economy such as that predicted by Veblen. The most that one can reasonably expect is that they retain a regard for the general public as well as for the owners of industry, and an absence of reactionary tendencies; and that they produce a few leaders capable of great detachment and with a sharp eye to improvement. In these respects the Norwegian engineers show up remarkably well. Moderation, good common sense, and enlightened conservatism are blended in their thinking with a full measure of responsible liberalism. Though deeply concerned about the welfare of their class, they are also devoted —in their social philosophy as in their technical work—to the engineer's ideal of increased benefits to the rank and file of mankind.

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For convenience the characters æ, ø and ü are alphabeted respectively as ae, o, and u.